THE UNIVERSITY OF ALBERTA

RELEASE FORM

NAME OF AUTHOR: [illegible]

TITLE OF THESIS: The Effects of Yoga and the [illegible]

on Selected Physiological Parameters

DEGREE FOR WHICH THESIS WAS PRESENTED: Ph.D.

YEAR THIS DEGREE GRANTED: Spring 1978

Permission is hereby granted to THE UNIVERSITY OF ALBERTA LIBRARY to reproduce single copies of this thesis and to lend or sell such copies for private, scholarly or scientific research purposes only.

THE UNIVERSITY OF ALBERTA

RELEASE FORM

NAME OF AUTHOR: Vethasiromani Hubert Dhanaraj

TITLE OF THESIS: The Effects of Yoga and the 5BX Fitness Plan on Selected Physiological Parameters

DEGREE FOR WHICH THESIS WAS PRESENTED: Ph.D.

YEAR THIS DEGREE GRANTED: Spring 1974

THE UNIVERSITY OF ALBERTA

THE EFFECTS OF YOGA AND THE 5BX FITNESS PLAN ON SELECTED PHYSIOLOGICAL PARAMETERS

by

© VETHASIROMANI HUBERT DHANARAJ

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF PHYSICAL EDUCATION

EDMONTON, ALBERTA

SPRING, 1974

THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled "The Effects of Yoga and the 5BX Fitness Plan on Selected Physiological Parameters" submitted by Vethasiromani Hubert Dhanaraj in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

ABSTRACT

The growing popularity of Yoga and the paucity of evidence regarding its effects on bodily functions prompted the need for a scientific investigation. The study was intended to determine the physiological influence of Yoga in comparison with the effects of the 5BX Plan for Physical Fitness.

Fifty-one undergraduate male students of the University of Alberta, aged 17 to 22, volunteered to be the subjects. After the initial tests, they were randomly assigned to three treatment groups, namely Yoga, 5BX and Control. While the Yoga group was given training for six weeks in selected *Asanas* and *Pranayama*, the 5BX group was trained according to the 5BX Plan for the same period. The Control group did not receive any training, and they were directed not to change their normal life style, including the level of physical activity.

The post-training tests indicated that certain significant changes had taken place as a result of training. In the Yoga group, increases in basal metabolic rate, tidal volume in basal state, T-4 thyroxine, hemoglobin, hematocrit, red blood cell count, PWC_{130}, vital capacity, chest expansion, breath-holding time and flexibility were observed, while decreases in heart rate in basal state and respiratory rate in basal state were noticed. The 5BX group increased in PWC_{170}, PWC_{130}, maximal O_2 consumption, vital capacity, chest expansion, breath-holding and flexibility, and decreased in heart rate in basal state and respiratory rate in basal state. Tests on pulse deceleration indicated that *Savasana* is an effective way of recovering from the effects of exercise. The Control group showed no significant changes.

Following the six-week treatment, Yoga training was discontinued for six weeks and the detraining effects were studied. Significant decline in the values of PWC_{130}, flexibility and breath-holding time were noticed.

Seven subjects each of Yoga, TM and Control groups were used to study the influence *Savasana* and Transcendental Meditation had on metabolic rate. Both methods produced appreciable diminution in O_2 consumption, the TM being more significant than the other.

In response to a questionnaire of subjective evaluation, all the Yoga subjects reported that they felt euphoric and more relaxed after training.

ACKNOWLEDGEMENTS

The author of this dissertation would like to place on record here his grateful thanks and sincere appreciation to:

Dr. M. Singh for his invaluable guidance, continued and unstinted advice and help which facilitated a better understanding of Exercise Physiology and enabled this researcher to complete his study;

Dr. N.R. Thomas, Dr. R.B.J. Macnab, Dr. W.D. Smith and Prof. L.J. Fournier for their encouragement and participation as members of the Thesis Committee;

Dr. W.A.R. Orban for serving as the External Examiner;

The fifty-one subjects for their interest and cooperation;

The helpers for their technical assistance;

Dr. M.L. Van Vliet for his valuable help in getting reference materials from India; Dr. D. Fawcett for his guidance and help in matters related to Endocrinology; Dr. M.V. Bhole and Prof. M.L. Gharote for their help in gathering information on Yoga research; and Dr. W.A.R. Orban for his assistance in the collection of facts concerning the 5BX Fitness Plan;

Wife Mrs. Sophia Dhanaraj for her unfailing help in tabulating the results;

Kith and kin, who in a faraway land, constantly remembered him in their prayers; and

Last, but not the least, in a special and personal way to his revered friend in India, Dr. L.K. Govindarajulu for his scholarly direction and for his timely advice that, "In a sense, the true researcher is a Yogi in himself because of his capacity for concentration." After

three years of academic pursuit filled with rewarding experiences, all that the author knew was that he became a Yogi!

TABLE OF CONTENTS

CHAPTER PAGE

CHAPTER PAGE

CHAPTER PAGE

CHAPTER PAGE

LIST OF TABLES

LIST OF FIGURES

LIST OF PHOTOGRAPHIC PLATES

CHAPTER I

STATEMENT OF THE PROBLEM

INTRODUCTION

Right from the dawn of civilization, man had evinced a keen interest in strengthening his body and attaining fitness for survival against the dangers of his environment. Systems of physical training should have evolved gradually in later years when life became more organized and purposes were established. Among the ancient systems of training that have stood the tests of time, the system of *Hatha* Yoga ranks as one of the oldest, and what more, as one of the most comprehensive and integrated systems ever known to man. In the absence of authentic records concerning the inception of Yoga, the popular belief is that it had its origin in India some 5000 years ago (121).

Known to the general public as a physical discipline, *Hatha* Yoga is a branch of Yoga which is interpreted as Union with the Divine. As Aurobindo (10) would have it, the implication is the Union of the Individual Soul with the Universal Soul. Bernard (17) refers to *Jivatman* or the Individual Spirit and *Paramatman* or Universal Spirit, and the linking of the two as the aim of Yoga.

In relating the philosophy of Patanjali, the author of the earliest treatise on Yoga called Yoga *Sutras* or Yoga Aphorisms, Aranya (6) emphasizes that true Yoga is practiced with a view to

attain spiritual liberation called *Mukti* or Salvation. Some writers express the purpose differently; for instance, Krishna (69) describes Yoga as a serious quest intended to lead the aspirant to a state of inner illumination. However, it is obvious, as Govindarajulu (54) would have it, Yoga procedure is essentially spiritual and the underlying endeavor is for Union, indicating that the individual is but a microcosm of the macrocosm. Despite this spiritual orientation, Yoga is non-sectarian, having a universal application or appeal to all mankind; and Radhakrishnan (93) has endorsed these opinions.

To achieve his final goal, the ardent follower of Yoga, who is known as Yogi or Yogin, has to go through eight steps or stages, of which *Samadhi* or Intense Concentration is the final one (92). *Samadhi* is a state in which the Yogi is totally oblivious of his environment. The eight steps are *Yama* or Restraints, *Niyama* or Observances, *Pratyahara* or Abstraction, *Asana* or Static Exercise, *Pranayama* or Breath Control, *Dharana* or Concentration, *Dhyana* or Meditation and *Samadhi,* the final stage of Yoga which culminates in *Nirvana,* the "cessation" of individual existence by becoming one with the Universe.

Asanas or *Asans,* meaning Seats or Postures, are static physical exercises; and so differ from normal dynamic exercises, while *Pranayama* consists of special exercises involving various methods of breath control. *Asanas, Pranayama* and *Kriya* or Yogic Hygiene are the three components of *Hatha* Yoga which forms a part of the Yoga System as the fifth branch, the other four being *Karma* Yoga or Yoga of Selfless Service, *Bhakti* Yoga or Yoga of Devotion to Supreme Being, *Jnana* Yoga or Yoga of Wisdom and *Raja* Yoga or Yoga of Restraint.

Hatha Yoga indeed shares with other branches of Yoga the original concept of contemplation for the attainment of salvation, but its means are different. *Asanas* are used for eliminating the weaknesses of the body, then strengthening it and thereafter, attaining the capacity for concentration through specific methods of breath control. Since the system of *Hatha* Yoga lays the foundation for a strong and healthy body under the perfect control of the Yogi and has been time-tested, it has by gradual stages come into popular usage as a means of gaining both physical fitness and strength, and balance of the mind required for effective living in the mundane world.

Turning to the modern scene, in recent years many training methods have been developed to promote physical fitness. One such method is the Five Basic Exercise Plan for Physical Fitness, popularly known as 5BX, which has been followed by many in Canada for some years. The 5BX Plan is based on selected calisthenic exercises meant to be vigorously performed over a short period of time. Such dynamic exercises stand on a completely different footing - different from static exercises like the Yogic *Asanas*. A comparative study of the efficacy of two divergent systems should be useful in extending our present knowledge of exercise physiology.

THE PROBLEM

The principal problems were:

1) to ascertain the training effect of *Hatha* Yoga on basal metabolic rate, 2) to ascertain the training effect of 5BX on maximal

O_2 consumption and 3) to ascertain the immediate effect of *Savasana* and TM on metabolic rate.

The sub-problems were:

1) to ascertain the training effects of *Hatha* Yoga on physical work capacity, thyroxine, red blood cells, heart rate, plumonary volumes and flexibility, 2) to estimate and compare the training effects of the 5BX Plan on the same parameters, and 3) to determine the effects of de-training, following *Hatha* Yoga training, on the same parameters.

HYPOTHESES

For purposes of examining the principal problems in this research, the null hypotheses were established as follows:

1. There will be no difference in the effects of the three treatments (Yoga, 5BX and Control) on BMR.

2. There will be no difference in the effects of the three treatments (Yoga, 5BX and Control) on maximal O_2 consumption.

3. There will be no difference in the effects of *Savasana* and TM on the metabolic rate.

RATIONALE BEHIND THE STUDY

For centuries, Yogis have been proclaiming and demonstrating their ability to develop voluntary control over certain autonomic functions of the body. It is of special interest to note, in this connection, that orthodox Yogis seriously devoted to Yogic ideals never made claims, and they shunned publicity.

Hoeing (58) conducted a study on a Yogi who allowed himself to be buried underground for nine hours in an airtight pit which

contained sufficient oxygen for two hours only. On opening the pit after nine hours, the Yogi was found to be normal and cheerful. Bhole et al. (22) observed that in such experiments, the so-called airtight pits do allow some diffusion of gases to take place.

In the experiments of Wenger et al. (119), and Anand and Chhina (4) on heart control, the conclusion was that the Yogic subjects were able to slow down the heart rate and so reduce the amount of blood flow that (a) the pulsation in the radial artery disappeared and (b) cardiac sounds became inaudible to auscultation. The tracings of the electrocardiogram, however, indicated that the heart had continued to beat. Even so, the voluntary control over the pace of the heart is a remarkable feat. Reporting on the findings of a similar experiment, Bhole and Karambelkar (19) stated that the electrical activity of the heart was absent for 3 to 5 seconds. As Joshi (64) pointed out, such miraculous control, as is evidenced in these experiments, must be regarded as the outcome of long submission to Yogic discipline and devoted training.

The effects of Yoga are indeed of special interest to science, and they reveal man's physical capacities; but it is a moot question if Yogic regimen which is life-long can be used by people in the prevailing conditions of living. Hence, it may be of advantage to consider the effects of short-term Yogic training on a scientific basis. This study was intended to serve such a need.

Hatha Yoga enjoys a wide following throughout the world, and there must be sufficient reason for such zealous interest in it. But, there is paucity of medical and other scientific evidence on the

effects of *Hatha* Yoga on the human body. Because of the apparently fanciful claims made about the efficacy of Yoga as being curative in its effects, there is a widespread interest and curiosity in regard to Yoga among the research-minded scholars.

Govindarajulu (55) urged that literature on the subject is hardly scientific and though there is a great deal to be said in its favor, one has to move with caution. Day (36) affirmed that the extravagant claims made about Yoga postures should be accepted with reserve. It is, therefore, obvious that there is a need for more scientific probe concerning the effects of Yoga training.

For ages, the Yoga system was based on traditional methods, largely on the basis of hypothetical reasoning and master-to-disciple instruction. The training was always comprehensive and complete. The influence of individual *Asanas* received no special consideration; and the scientific basis of each Pose was not investigated till Kuvalayananda (70) started his inquiry and inferred that particular *Asanas* produce particular effects. Based on his findings, he recommended a set of a few *Asanas* with certain specific functions and arranged them in some sequence to meet present-day needs of busy urban people in terms of time and convenience; but Kavalayananda's findings still need confirmation and the outcomes have to be carefully assessed by further research.

In this study, the subjects of the Yoga group had to follow a schedule of five *Asanas* and two breathing exercises, these later being part of a Yoga procedure described as *Pranayama* as already indicated, and the schedule itself was similar to the 5BX Plan from the

point of view of time and convenience,and were meant for urban surroundings. The *Asanas* were so selected as to typify in miniature a round of the more effective *Asanas*, involving flexions of the spinal column primarily, but having different gravitational effects in a static position. A short period of silence was included so as to provide an atmosphere conducive to keeping the mind calm. No restrictions were placed on the subjects during the period of training; and subjects were asked to maintain their normal routine of living in order to secure conditions of participation similar to those using Yogic methods in the Western environment.

Yogic *Asanas* involve severe flexion of joints of both limbs and the spinal column, and static maintenance of the body in various positions. Such body positions accompanied by joint constrictions seem to divert blood flow so as to influence increased circulation in some parts, as against others. Simultaneously with the performance of the exercises, the mind is centered around or fixed on some object of concentration; and this would seem to affect nerve stimuli, and cause consequent physiological changes.

Hatha Yoga, being just one of modern man's endeavors to develop and maintain physical fitness, a comparison of its physiological effects with those of a standard physical training program should reveal interesting facts. With this in view, the Canadian 5BX Plan for Physical Fitness was selected for such a comparison. The study had thus a double purpose of determining the effects of each of the two methods and comparing the measurements so obtained on different parameters.

One of the physiological parameters considered was O_2 consumption, a key factor in body metabolism. The metabolic rate which fluctuates according to bodily conditions is a fundamental biological process in man. The range between low metabolic rate as evidenced in the basal state and high metabolic rate as indicated in strenuous work, accounts for the maximum being a certain number of times greater than the minimum and this provides an interesting concept. As early as 1936 Dill (42) introduced the idea of expressing energy requirements in terms of multiples of BMR. Banister and Brown (12) favored Dill's approach as it takes into account individual differences due to body size, age and sex. With this in view, an attempt was made in this study to determine metabolic rates at the basal and maximal levels, and establish the significance of their differences.

The energy exchange in the body at the basal level as determined by BMR serves to give the physiologist an indirect index of thyroid function. In the current clinical scene, the BMR measurement is regarded as only next in importance to the more convenient blood tests. Nevertheless, as Becker (15) pointed out, the BMR remains unique and irreplaceable as the only quantitative measure of total body energy production readily available to the clinician. It is obvious that the problem is not related to the reliability of the test but in establishing the basal state that is so essential. The subjects used in this study were given detailed instructions regarding preparation for the tests and were briefed from time to time, and it was evident that they understood the purpose of the experiment and their responsibilities in it.

In defending the merit of BMR, Keating (65) stressed that its usefulness is augmented when considered in conjunction with alternative and newer procedures. An approach along that line was made in this study as well, though in a limited way, by obtaining additional information from T-4 tests. The BMR test also provided supplementary data on BT, HR, RR, TV and RQ all in the basal state; and such data ensured a better understanding of the effects of training.

Metabolic rate would seem to be influenced by emotional conditions. Those with proper attitudes to exercise and rest are better able to relax and thus maintain a lower metabolic rate than would otherwise be possible. This is conducive to economy of energy. The Yogic technique of relaxation called *Savasana* and a modern version of Yogic meditation known as Transcendental Meditation are considered good to prevent stress or relieve it, and enhance the capacity for relaxation and mental poise. To test and compare the effectiveness of these two methods, tests on O_2 consumption were done in this study.

Physical training and detraining are interrelated and our present knowledge of physiology is by no means complete in this regard. There are many functions of the human body, the secrets and implications of which have not been fully disclosed by research. For a proper understanding of the lasting effects of training, it was felt necessary to make a study of the effects of discontinuation of training. This matter has practical significance as many young adults train and detrain over a period of several years. An effort was made to probe the problem to a limited extent, and the Yoga group was used to study the effects of detraining for six weeks.

LIMITATIONS OF THE STUDY

1. The subjects were asked to continue during the period of experiment the style of life to which they were used, including physical activity, and no control was established on their normal activities.

2. Everything possible was done to maintain the enthusiasm for participation in the training and tests, but motivation and interest were independent of the researcher's control.

3. The study was limited by the individual ability of each subject to understand and follow the instructions relative to training and testing.

4. The ability of the subjects of the Yoga group for concentration on a single thought was beyond the researcher's control.

5. No control could be exercised over the subjects all through the period of detraining, during which they were asked to discontinue the practice of Yogic exercises used in their earlier training, but maintain their normal routine of living.

DELIMITATIONS OF THE STUDY

1. Fifty-one male students aged 17 to 22 voluntarily participated in this study.

2. Five selected *Asanas* and two breathing exercises combined with concentration formed the regimen of the Yoga group.

3. Four minutes of extra exercises were added to the 5BX Plan to equalize the time factor involved in the training of the two experimental training groups.

4. Twenty-one subjects were used in the experiment on *Savasana* and TM.

5. Unlike the Yoga and 5BX groups, the TM group was not trained by the researcher. The subjects of the TM group practiced meditation on their own.

DEFINITION AND ABBREVIATION OF TERMS

Definitions

(1) Aerobic Capacity: The capacity to perform work when the intake of oxygen is sufficient to meet the needs.

(2) *Asana:* A static Yoga exercise or pose maintained for a specified period of time (asana = seat or pose).

(3) Basal State: A state established by the following: 1) the last meal eaten about 12 hours earlier, 2) 8 or more hours of sleep, 3) no muscular exertion, 4) no drug or stimulant that is likely to disturb the normal metabolic activity, and 5) mental relaxation.

(4) Detraining: Discontinuation of training for a specific period following a period of training.

(5) Maximal Oxygen Consumption: The maximum amount of oxygen the cardiorespiratory system can absorb, transport and deliver to the working tissues.

(6) *Pranayama:* An element of Yoga involving specific kinds of respiratory control (prana = breath; yama = control).

(7) *Savasana:* An *Asana* performed in a supine posture for relaxation (sava = corpse; savasana = death pose).

(8) Yoga Practitioner: One who practices Yoga in order to improve his health and fitness.

(9) Yoga Professional: One who performs Yoga feats for purposes of publicity and proft.

(10) Yogi: An ardent follower of Yoga, devoted to the Yogic ideals and traditions as given in early Yoga literature.

Abbreviations

(1) BMR: Basal metabolic rate (estimate of energy expenditure in the basal state).

(2) BT: Body temperature (oral).

(3) 5BX: Five basic exercises (a plan of physical fitness exercises).

(4) HR: Heart rate (frequency per minute).

(5) Kcal/sq.m/hr.: Kolocalories per square meter of body surface in one hour (unit of measurement in basal metabolic rate).

(6) Kpm: Kilopond meter (unit of physical work measurement, based on kilopond which is the force acting on one kilogram of mass at the normal acceleration of gravity).

(7) PWC: Physical work capacity (ability to perform prolonged physical work, related to the heart rates of 170 and 130).

(8) Post-detrg.: Post-detraining (the period immediately after training has been discontinued for a specified period of time).

(9) Post-treat.: Post-treatment (immediately after an experimental treatment).

(10) Post-trg.: Post-training (the period immediately following training).

(11) Pre-treat.: Pre-treatment (just before an experimental treatment).

(12) Pre-trg.: Pre-training (the period just prior to training).

(13) RBC: Red blood corpuscles (the cells of the blood which carry hemoglobin).

(14) RR: Respiratory rate (frequency per minute).

(15) RQ: Respiratory quotient (ratio of carbon dioxide eliminated and oxygen absorbed, ie. $\frac{CO_2}{O_2}$).

(16) STPD: Standard temperature pressure dry (0°C, 760 mm. Hg., dry).

(17) TM: Transcendental Meditation (a standardized technique of meditation).

(18) TV: Tidal volume (volume of expired gases in normal respiration).

(19) T-4: T_4 value of thyroxine (an index of thyroid function).

CHAPTER II

REVIEW OF LITERATURE

I. HISTORICAL BASIS

I. a) Yoga

Yogic exercises were never meant for physical development exclusively. They were devised to so train the body as would enable the Yogi to withstand the strains of prolonged meditation for the unfolding of hidden faculties and to sustain and direct the working of spiritual forces when aroused (70). The physical aspect of Yoga was directed towards an all-round development of the Yogi rather than for merely obtaining specific physical qualities. The discipline was essentially part of a long-drawn spiritual procedure controlled and handled directly by the *Guru* or Master, who trained and tutored, and watched the *Shishya* or Disciple strictly according to individual needs, and in pursuance of the hoary traditions started by the ancient savants of India. The practice of Yoga did not admit group instruction accordingly (50), on the realization that each individual was a distinct entity demanding individual guidance.

The selection of exercises and the intensity of training were left entirely to the discretion of the *Guru*; but the *Shishya* had to be both devoted and regular, and incorporate Yoga into his normal life style to ensure progress. The outcomes of such a long-term training were subjectively evaluated by the *Guru* from observations of the overall progress of his *Shishya*.

Hatha Yoga, one of the five branches of Yoga, was itself an integrated system comprising *Asanas, Pranayama* and *Kriya;* and all of these collectively served to lead the aspirant towards his spiritual goal. To this end, serious practice was devoted to the awakening of the *Kundalini Shakthi* - an occult or hidden power that lay dormant in the lower spine (92). The physiological implications of this phenomenon have not been revealed by any modern research. It is said that the occult power is awakened only by the individual's self-effort, under the guidance of the *Guru,* as the result of deep and continued meditation.

It would appear that much emphasis was laid on the development of the nervous system and endocrine glands; and consequently, controls were established on such emotions as were likely to cause any hindrance to progress. Discipline formed an essential part of Yoga training. One of the purposes of the first two steps to Yoga was to obtain freedom from disturbing emotions; hence the *Yama* and *Niyama* procedures or Abstentions and Observances with which the Yogi had to start (92). The establishment of the mental homeostasis was accordingly considered the foundation on which to build both physical and spiritual strength.

Certain *Asanas* were used by Yoga devotees as seats for meditation. According to Kuvalayananda (76), such meditative poses were based on three physiological functions: 1) An erect position of the trunk to eliminate the possibility of compression of the abdominal viscera; 2) richer blood supply to the pelvic region; and 3) easy relaxation and mental concentration to reduce the metabolic rate. But, the more important reason would appear to be that meditative poses

ensured an erect spine essential to the free function of the nerve trunk and its accessory nerves.

The votaries of traditional Yoga have, however, tended to diminish in number over the years; and the recent interest in Yoga and its phenomenal popularity have evoked the attention of scientists to this ancient system. The evolution of the modern system of *Hatha* Yoga training has thus resulted in the detachment of *Asanas* and *Pranayama* from their original purposes as a purely spiritual discipline. Consequently, the physiological aspects of Yoga have today assumed greater importance. Kuvalayananda pioneered the scientific orientation, and introduced a scheme of research based on medical knowledge; and his work had, since 1924, aroused world-wide attention (54). Following that lead, limited physiological experiments have been carried out, though at random, and in different countries.

There is still no proper understanding of the physiological effects of Yoga; and our knowledge of the causes underlying bodily changes due to Yoga is yet obscure. Govindarajulu (54) pointed out that misconceptions still shroud the ancient system of Yoga in mystery, and a comprehensive assessment of the nature and value of Yogic *Asanas* remain yet to be made by scholars trained in modern methods of scientific research.

I. b) 5BX Plan

The concept of a Basic Exercise Plan was conceived in 1956 after Orban (89) had completed a survey of the Royal Canadian Air Force training establishments across Canada. The Five Basic

Exercise Plan for Physical Fitness came into existence in 1957. It consisted of five dynamic exercises, meant to be done in eleven minutes. The Plan was based on progression, moving from work of lower intensity to higher intensity.

Originally designed for the Air Force personnel, the 5BX Plan was made available to the public through the publication of a self-explanatory handbook. The third edition (102) printed in 1970 (which retains the original structure of six progressive stages, given in six Charts) is now in circulation.

No recent survey on a national scale has been conducted to assess the popularity of the 5BX Plan. The sponsors of this Plan claim that their own research has demonstrated that it improves the efficiency of the heart and the lungs, and increases the capacity for physical exertion (102); but the research findings have not been published. Accordingly, reports of other works have to be considered.

Cureton (32) criticized the 5BX Plan on the ground that its energy cost does not total 100 calories, and hence, the intensity is insufficient to elicit a significant training effect. Banister and Brown (12) reported that the energy expenditure of exercises given in the sixth Charts (101) are in the range of 92-194 calories (8.4 to 17.6 Cal/min.).

I. c) Transcendental Meditation

Transcendental Meditation is a simple mental technique which comes from the Vedic tradition of India (123). A modern system of TM was developed by Maharishi Mahesh Yogi. The technique is now uniformly taught by teachers trained by Maharishi; and it is described

as enjoyable and requiring no special mental control or unusual postures (90). TM is now said to enjoy a wide following in America, Europe and Australia.

The physiological effects of TM have been drawing the attention of scientists in recent years. TM practitioners seem to acquire a certain emotional stability, and are less susceptible to the debilitating effects of stress. Several physiological changes are said to accompany the meditational practice of which the hypometabolic condition is of prime interest (117). Research literature on the subject has grown steadily and rapidly since the appearance of the first studies by Wallace in 1970 (114). The number of researchers engaged in defining the physiology of TM is increasing at a phenomenal rate; and such a proliferation is attributed to the growing scientific curiosity in the West.

II. PHYSIOLOGICAL EFFECTS OF YOGA

II. a) Basal Metabolic Rate

In a study on *Bhugarbha Samadhi* or Underground Burial, Bhole and Karambelkar (22) determined the BMR of a 50 year-old Yoga Professional and three Yoga Practitioners (14, 55 and 63 years). The Yoga Professional's BMR was -7% and that of the others were -2%, -4% and -3%. During the actual period of the Burial (stay in an underground airtight pit) the metabolic rate was found to be lower than BMR in all the subjects. The investigators attributed this to the ability to maintain homeostasis even under stressful conditions developed through *Pranayama* and rejected the premise of voluntary control over one's own metabolism.

Gharote (51) investigated the influence of Yoga Meditation on energy expenditure, using a 32 year-old Yoga Practitioner as the subject. The subject had a BMR of 37.0 Kcal/sq.m/hr. During the state of meditation, the metabolic rate was measured three times at an interval of 15 minutes. The third measurement was the lowest, and the mean of the three values equalled 29.7 Kcal/sq.m/hr. Prolonged sitting in meditation brought about a decrease in metabolic rate rather than an increase.

Romanowski et al. (100) administered physiological tests on 15 men (aged 19 to 56), who had practiced Yoga for at least one year. The RQ observed in the basal state was low, indicating a greater utilization of O_2 by the tissues.

In an experimental study, Rangan (94) investigated the effects of *Sarvangasana* and *Halasana* on BMR. Twelve male students of a physical education institution were trained for six weeks. The tests indicated that their BMR increased significantly (31.9 to 35.6 Kcal/sq.m/hr.). The BMR of the control group which participated in a general program of physical activities for the same period was not altered to any appreciable degree.

II. b) Thyroid Function

It looks as though the ancient Yogic seers surmised the existence of endocrine glands and their general functions, long before the advent of modern science. Devi (37) stated that Yoga postures were designed to correct the sluggish functioning of the endocrine glands and thereby, promote good health and fitness. It would appear that in training for functional efficiency, the endocrine system was

used effectively. Thus, ancient *Hatha* Yoga stands diagonally opposite the modern physical training system based on dynamic big muscle activities and heavier work loads intended to exercise and develop various parts of the body.

The developments in the science of human physiology, which have led to an understanding of hormones and their importance to organic function have impelled recent workers to think that *Asanas* influenced the thyroid and other hormone functions. Chidananda (29) referred to a stimulating effect on the thyroid brought about by regular practice of *Asanas* and to the corrective value of *Asanas* in glandular malfunctions. This hypothesis was expressed in different ways by various authors including Kuvalayananda, Majumdar, Rele and Yogendra (72, 79, 97, 122).

Sarvangasana described as the Pan Physical Pose came to be regarded as a special exercise for stimulating thyroid function. Since the time Kuvalayananda started his Yoga research about fifty years ago, *Asanas* like the *Sarvangasana* have been associated with therapeutics. From the Yogic point of view, the indications are that *Sarvangasana* has been considered to be efficacious in dealing with both hypothyrodism and hyperthyroidism, and the *Asana* is invariably added to every schedule of *Asana* exercises.

Reporting on the research findings of a Yoga research institute, Digambarji et al. (41) listed numerous diseases which have been successfully treated through Yoga practice. For more than 25 years, the institute had dealt with five goiter patients each year on an average, treating them with just Yoga practices and regularized

daily routine of life, without medication. The results indicated that all their subjects showed favorable response, and were either cured, or their condition improved significantly.

Sarvangasana is essentially a shoulder stand, wherein the feet, trunk and legs are stretched overhead with the feet in line with the forehead and the chin pressed against the upper end of the sternum with jugular notch to form a Chin-lock (54). A liberal supply of blood to the thyroid gland caused by the inverted body position, and the compression in the location of the thyroid gland brought out by the Chin-lock are considered the key factors in the *Asana*. A combination of these two factors is probably essential to expect the desired results. *Viparita Karani* which is an inverted pose (somewhat similar to *Sarvangasana*) without the Chin-lock and *Jalandharabandha,* a process of tightly fixing the chin on the chest (somewhat similar to Chin-lock in *Sarvangasana*) performed in a sitting position, do not seem to have any special influence on thyroid function (73, 75).

According to Kuvalayananda, Yoga helps to eliminate mental depression considered to be one of the causes of hypothyroidism. Freedom from tensions and anxieties is secured, and a feeling of contentment is cultivated through proper Yogic training. The practice of selected *Asanas* coupled with mental poise will act on the thyroid gland and enhance or control its function (74).

Rangan (94) tested 12 normal, young adults before and after 6 weeks of training with *Sarvangasana* and *Halasana*. Based on a significant change in BMR, he concluded that the activity of the thyroid

gland was influenced by the practice of these two *Asanas*.

II. c) Red Blood Cells

Rele (97) claimed that Yoga training is beneficial in developing and maintaining the quality of the oxygen - transport system in the body. There is some clinical evidence that Yoga may induce some changes in blood composition. Bhole and Karambelkar (20) studied the effects of Yoga training ranging from 4 to 6 weeks on 104 asthma patients aged 18 to 80 years without any cardiac complications and kidney or liver dysfunctions. They observed an over-all increase in hemoglobin concentration (14.0 to 14.6 gm/100 ml.). However, experiments performed on normal persons would only provide the type of information the exercise physiologists need.

II. d) Cardiovascular Fitness

Bhattacharya (18) who observed the athletic performances of Yoga Practitioners for several years, expressed the doubt whether *Asanas* would contribute to cardiovascular fitness. This would appear to be the popular opinion of Yoga researchers and writers, though in recent years there has been some evidence to the contrary.

Digambarji et al. (41) reported that school children trained in Yoga for 6 weeks showed signs of improvement in cardiorespiratory efficiency and athletic ability.

Romanowski et al. (100) examined trained Yoga Practitioners to determine their ability to perform endurance exercises. The subjects found it hard to manage a work load which was moderate for others trained in sports. However, the oxygen debt suffered by the Yoga

Practitioners was smaller and their recovery from fatigue was faster. The researchers attributed this partly to their mastery of relaxation.

Reporting on the findings of the experiments done at a Yoga research institute, Digambarji et al. (41) stated that the immediate physiological response to *Asanas,* as performed by skilled Yoga Practitioners consists of 1) moderate muscular activity as determined by electromyography, 2) limited rise in blood pressure, indicating the absence of strain on the heart, 3) low O_2 consumption applicable to mild physical activities, and 4) diminished uropepsin in urine, indicative of reduced corticoid production, and consequently of a state of reduced stress and tension.

Dhanaraj (40) trained 13 young adults (9 men and 4 women, aged 18 to 27) in selected *Asanas,* 4 days a week for 6 weeks. Tests following the training indicated that the average HR of the subjects doing the *Asanas (Bhujangasana, Sarvangasana, Halasana* and *Matsyasana),* measured during the third minute of continuous performance was 86.

Rao (95) determined the metabolic cost of *Sirshasana,* described as the Topsy-turvy Pose or Head-stand, using 6 male volunteers, aged 19 to 22 years, as subjects. The amount of O_2 consumed during the exercise was found to increase 48% above the value obtained in standing position, indicating that *Sirshasana* is a light form of muscular exercise. This observation suggests that the energy cost of *Asanas* is rather low, and for this reason, *Asanas* cannot be regarded as endurance exercises. *Asanas* may be normally regarded, for the same reason, as non-fatiguing activities.

It is generally assumed that there is some threshold for a training effect on the cardiovascular system. The need for a high intensity of training, selected according to the age group, to elicit improvements in cardiovascular fitness was reported in the study by Shephard (103). There are indications that about a 100 percent rise in HR (above the resting level) will bring about some beneficial changes. While the intensity of training appears to be the major stimulus in improving an individual's cardiovascular fitness, the usefulness of *Asanas* which can elevate the HR to about a mere 50 percent is subject to critical examination.

According to available information, the resting HR tends to be lowered as a result of Yoga training. Romanowski et al. (100) tested 15 men (aged 19 to 56 years) who had practiced Yoga for over 1 year. Low values were obtained in resting HR (range = 56 to 62 per min.) and arterial blood pressure (range = 104/68 to 120/72 mm.Hg.).

Udupa et al. (112) trained 12 young male volunteers (mean age = 23 years) for 6 months. The tests following the training indicated that their mean resting HR had decreased from 66.6 to 62.2 beats per minute.

Dhanaraj (40) found a significant reduction in the mean resting HR (64.3 to 58.8 beats per min., measured in the basal state) of 13 young adults who were trained for 6 weeks. In the same study, no appreciable difference was observed in their maximum HR (194.6 to 193.1 beats per min.).

II. e) Respiratory Measures

1) Respiratory Rate: Romanowski et al. (100) tested the RR of several men who practiced Yoga for some years. The mean frequency in the basal state was recorded as 4.2 per min. The changes in TV and minute ventilation were not observed. The investigators reported that the subjects also showed a steady rhythm of breathing.

2) Vital Capacity: Physical education teachers who attended summer courses in Yoga lasting a month, were the subjects in an extensive study conducted by Bhole and Karambelkar (21). A total of 147 subjects (aged 18 to 50 years) were tested and it was found that the mean vital capacity increased from 3.4 to 3.6 liters.

Udupa et al. (112) observed a significant difference (3.7 to 4.6 lit.) in the vital capacity of 12 male subjects (mean age = 23.0) trained for 6 months. A mid-training test indicated that it had increased from 3.7 to 4.3 liters in 12 weeks.

3) Chest Expansion: Day (36) pointed out that those who specialize in the Yoga-type of breathing exercise claim their ability to increase their chest expansion by 7 or more centimeters in a matter of weeks. Udupa et al. (112) reported that the average chest expansion of 12 young male subjects increased from 3.4 to 4.3 cm. in the first three months and from 4.3 to 4.7 cm. in the second three months, of their 6 months training.

4) Breath-holding: A male subject aged 32 trained in Yoga breathing was tested by Miles (85). The subject returned a time of 2 min. 6 sec. which could be considered normal for an experienced Yoga Practitioner.

In an experimental study, Udupa et al. (112) observed that *Hatha* Yoga training caused a substantial increase in breath-holding time (74.8 to 99.3 sec. in three months, and 74.8 to 101.2 sec. in six months).

Bhole and Karambelkar (21) noticed considerable improvement (77.6 to 92.3 sec.) in their 139 subjects (aged 18 to 50) of a short-term training program.

II. f) Flexibility

DeVries (38) made a comparative study of the effects of *Asana*-type exercises and regular fast stretching exercises, and found no significant difference between the two methods. The researcher, however, pointed out that in Yoga training there is less danger of exceeding the extensibility limits of the tissues involved.

Govindarajulu (54) classified a set of *Asanas*, recommended for inclusion in physical education, into categories based on their movements, and pointed out the wide variety of flexion involved in Yoga training. Different *Asanas* using flexions of the joints anteriorly or posteriorly could ensure different effects on organic functions, since static positions lead to differences in the quantum of blood circulating in the upper and lower regions of the body.

Based on experimental evidence, Rathbone (96) suggested the use of the methods of *Hatha* Yoga for the improvement of muscle tone and flexibility. Majumdar (79) stated that *Asanas* represent a unique way of developing the strength and flexibility of the spinal column. Digambarji et al. (41) outlined the scope of Yoga as a means of improving flexibility and physical efficiency for all people.

The effects of *Asanas* on the different aspects of joint flexibility have not been scientifically studied. However, the principles on which Yogic *Asanas* are based are being appreciated; and they are now being increasingly applied to athletics.

II. g) Relaxation

Yoga literature lays considerable emphasis on *Savasana* as an effective way of attaining a restful condition. *Savasana* consists of relaxing in supine position, while maintaining a certain rhythm in breathing and a calm mind. It is meant to be practiced as a conscious and systematic technique; and it is not just allowing inertia or inactivity to take over. Hence, *Savasana* has always been considered an *Asana*, and like all other *Asanas* it is based on certain principles of willed effort.

Reporting on the findings of many years of research at Lonavla and Bombay, Digambarji et al. (41) asserted that the general capacity for relaxation is enhanced by Yoga training. In the opinion of Vinekar (113) *Savasana* is a very efficient procedure for relaxation and is helpful in removing both physical and mental tensions. The physiological influence of this *Asana*, especially its energy cost, and the effects of Yoga training on relaxation do not appear to have been fully investigated by controlled experiments. Datey et al. (34) have, however, used *Savasana* in treating hypertensive patients. After a few weeks of treatment, the blood pressure was found to be significantly lower (134 mm.Hg. reduced to 107 mm.Hg. in one of the experiments). The investigators also reported that nervousness, irritability and insomnia disappeared in almost all the patients.

II. h) Detraining

Traditional Yoga literature naturally makes no mention of detraining, as Yoga was offered as a way of life. But, to test its value scientifically as a help to present-day living, Gharote (52) trained 44 subjects (aged 13 to 19 years) for 2 months and then, allowed them to detrain for 2 months. The tests on volar conductance, diastolic blood pressure and certain other psycho-physiological measures indicated that the effect of training (a shift towards increased parasympathetic function) had a residual influence and lasted even after the lapse of 2 months of detraining.

III. PHYSIOLOGICAL EFFECTS OF 5BX

III. a) Metabolic Cost

The introduction of the 5BX Plan created some doubts concerning its intensity and metabolic cost. Stallman (106) evaluated the metabolic cost of 5BX on a limited scale and reported the range for Charts 1 to 6 as 489 to 625 Cal/hr. Landry (77) studied the problem more extensively and concluded that the values for Charts 1 to 3 alone were 458 to 773 Cal/hr. Both studies used conventional metabolic methodology and true assessments were necessarily hampered by the inconvenient equipment the subjects had to use during the tests (13).

Banister et al. (13) evaluated the metabolic cost of the six Charts at the A+ level, using a closed circuit Rebreathing Respirometer. The chamber was spacious, with adequate arrangements for controlling internal temperature and humidity, and there was no need for the subjects to burden themselves with any measuring device or wear any equipment. The tests indicated that the metabolic cost of the

six Charts ranged from 92 to 194 calories (8.4 to 17.6 Cal/min.). The researchers observed a break in the progression of the Charts, inasmuch as the metabolic demand of Chart 3A+ was slightly larger than that of Chart 4A+.

III. b) Cardiovascular Fitness

Alexander et al. (1) trained 10 young men according to the 5BX Plan for 6 weeks. The subjects were tested on treadmill performance, consisting of the measurement of the time taken for the pulse to reach 180 while walking at 3.3 miles an hour, with grade increments of 1% per minute. Their average performance increased from 14.6 to 17.6 minutes, although they were below a group of trained hockey players, who had a mean performance time of 20.6 minutes. The researchers also reported that the 5BX subjects' mean resting HR, and HR after two minutes of exercise decreased progressively with training, increasing performance time.

Cooper (31) used thirty male subjects (mean age = 19.6 years) to compare the effects of 5BX Plan and a Circuit Training method. Ten subjects followed the 5BX Plan, 5 days a week for 5 weeks, while 10 other subjects participated in a Circuit Training program, the remaining 10 acting as Control. The tests included walking on treadmill (3.4 miles an hour and grade increased by 1% each minute) until HR reached 180, and running on treadmill (7 miles an hour and grade at 8.6%) to exhaustion. The 5BX group gained 1 min. 42 sec. in the first test, and 54 sec. in the second. The Circuit Training group gained 1 min. 36 sec. in the first test and 1 min. 1 sec. in the second. It was found that there was a reduction in the resting HR

of the two groups by 2 to 9 beats per minute. The 5BX group had reductions in exercise HR greater than that of the Circuit Training group. The pulse deceleration following exercise in the first test improved in both the groups.

III. c) Respiratory Functions

Alexander et al. (1) reported that young male subjects trained in 5BX for 6 weeks showed certain improvements in respiratory functions. Measurements at peak exercise made during and following the training period indicated a progressive increase in minute ventilation and O_2 consumption, with a decrease in O_2 extraction.

In Cooper's study (31) the subjects of the 5BX group improved their maximal O_2 consumption and exhibited a lowered RQ during exercise (compared to pre-training test results), indicating a better utilization of O_2.

IV. PHYSIOLOGICAL EFFECTS OF TRANSCENDENTAL MEDITATION

IV. a) Oxygen Consumption

Wallace (114) used 15 college students, who had been trained in TM in a study to determine the effects of TM on O_2 consumption. A sample of expired gases was collected after 20 minutes of habituation, with the subject seated in a chair. The second sample was collected during 30 minutes of meditation immediately following the period of habituation. The test results indicated a drop of about 20 percent in O_2 consumption (244 to 201 ml/min.). The RQ was observed to be fairly constant throughout the experiment. The researcher explained the meditative state as a condition of restful alertness,

different from sleep or hypnosis, which lowered the metabolic activities of the body.

Wallace et al. (117), and Wallace and Benson (116) reported the physiological effects of TM on 28 men and 8 women (mean age = 24.1 years). The experience of the subjects in meditation ranged from less than a month to 9 years, with the majority having had 2 to 3 years of practice. Such a sampling was based on the belief that those who have undergone a course in TM may begin to derive its benefits within a few days. Two expired air samples were collected from each subject, one after 30 minutes of habituation in a sitting position and the other during 20 to 30 minutes of meditation. O_2 consumption decreased from 251 to 211 ml/min. CO_2 elimination decreased from 219 to 187 ml/min., indicating a fairly steady RQ. The researchers attributed this hypometabolic state to a softening action on the sympathetic nervous system.

IV. b) Heart Rate

Wallace (114) reported that HR of the subjects decreased during meditation, with a mean difference of 5 beats per minute.

In the studies of Wallace et al. (117), and Wallace and Benson (116) HR was not affected to any appreciable degree by meditation. The rate decreased on an average by 3 beats per minute.

IV. c) Respiratory Rate

In Wallace's study (114) no conclusion could be drawn on the effect of TM on the RR. It was observed that minute ventilation decreased, either due to a lower RR or a reduction in TV, which varied

from subject to subject.

Allison (2) studied the respiratory changes in one subject as he meditated. The RR dropped from 12 to 6 per min. and then fluctuated between 8 and 4 per minute.

Wallace et al. (117), and Wallace and Benson (116) observed a mean drop of 2 per min. in their subjects during meditation. The minute ventilation became less by 1 lit/min. on an average.

V. BASAL METABOLISM

V. a) Measurement

The energy exchange level in an individual's body in the fasting and resting state is called basal metabolism; and the value then determined is the basal metabolic rate. To obtain accurate results, the subject should be both mentally and physically relaxed and all basal conditions should be satisfied. BMR is at the lower end of the scale of energy expenditure, at the other end of which is the maximum O_2 consumption required for most strenuous exercise. According to Knoebel (68) basal metabolism does not represent the minimal functional activity of the body, since energy exchange is about 10% lower during sleep.

The metabolic activity of the body is directly influenced even by small changes in physical work. Banister and Brown (12) stated that reclining at 45° angle and sitting on a chair raise the metabolism 3.2 and 6.6% respectively above the supine resting value. The fact that metabolic cost could be lowered by reducing neuromuscular tension was demonstrated in a study conducted by Steinhaus and Norris (110).

The three largest and most authoritative sets of original data on basal metabolism, as reported by Passmore (91) are the Mayo Foundation Standards of Boothby and his associates, the British measurements of Robertson and Reid, and the Carnegie Nutrition Laboratory data of Harris and Benedict. Of these, the normal standards of Robertson and Reid (99) were based on two successive measurements made on each subject. It is obvious from these studies that the BMR is greater in men than in women and it tends to diminish with normal aging. Becker (15) stated that 5 year-old boys produce about 50 Kcal. of heat per square meter of body surface per hour; and by the age of 20, this decreases to about 39 Kcal.

BMR is most commonly measured by indirect calorimetry. The feasibility and reliability of this technique carried out by open circuit method, was described by Gemmill and Brobeck (49). The factors which influence the basal metabolic condition of the subject are found in the treatise of Brown and Brengelmann (25). They emphasize the importance of a judicious consideration of the factors influencing basal metabolism. Boothby and Sandiford (23) reported that the accuracy of the measurement could be enhanced by repeating the test.

DuBois (43) pointed out that determination of heat production in the basal state is a measure of the energy exchange required to maintain the vital activities of the body. The practice of converting the O_2 consumption into Kcal. and relating it to the body surface area in estimating BMR, has been generally accepted. Horrobin (61) confirmed the true relationship between the BMR and surface area of the body. Miller and Blyth (86) who advocated lean body as a metabolic

reference standard, pointed out that the surface area standard derives its validity from its correlation with lean body mass. According to Guyton (56) about 85% of a normal population would have the BMR within 10% of the mean.

V. b) Effects of Physical Training

In 1928, Steinhaus (108) pointed out that some researchers had reported an increase in BMR, some a decrease and some others, no change. This unsettled position seems to continue still. Kenhr et al. (67) studied the effects of track training on BMR over a period of six months and observed no significant difference. Bender (16) reported a significant increase in BMR in a group trained for endurance. Baisset et al. (11) found that the BMR of their subjects decreased after a period of physical training.

VI. THYROXINE

VI. a) Measurement

For many years, the BMR determination was used as an indirect method of assessing thyroid function, until the more convenient PBI (Protein bound iodine) test was introduced. In recent years, the PBI test has been replaced by the T-4 test (serum thyroxine) as a more reliable diagnostic measure. Ingbar (63) pointed out that the PBI test runs the risk of distortion, owing to the chances of the serum containing nonhormonal iodine, while the T-4 test is not generally affected by similar conditions.

VI. b) Effects of Physical Training

In a diet-controlled experiment, Rhodes (98) found that exercising rats stored only about half as much iodine in the thyroid as did the non-exercising controls. This was interpreted as an increased utilization of thyroid hormone to facilitate the conversion of additional dietary iodine to circulating hormonal iodine with a consequent decrease in the quantum of stored iodine. Nayer et al. (88) reported a significant increase of the free thyroxine level in human subjects after four months of athletic training.

VII. HEMOGLOBIN, RED CELL COUNT AND HEMATOCRIT

VII. a) Measurement

An evaluation of the dynamics of erythrocytes and hemoglobin seems to depend on the measurements of hemoglobin concentration, RBC count and the percentile volume of RBC. Hoffman (59) pointed out that changes in hemoglobin concentration generally cause disturbances in the other two factors, though not necessarily in a parallel manner.

VII. b) Effects of Physical Training

As early as 1933, Steinhaus (109) pointed out that RBC count, hemoglobin concentration and hematocrit are not likely to change due to any type of physical training. Since then, there has been no convincing evidence to prove or disprove that statement.

Davis and Brewer (35) used 5 sedentary dogs in an experimental study. Two dogs were exercised by swimming for 2 hours daily and 3 dogs were made to run on a treadmill on 25% grade for a distance of 6 miles daily. During the first week of exercise, a

reduction of cell volume, RBC number and hemoglobin concentration occurred. A reversal effect was observed during the later part of training. While hemoglobin concentration returned to normal, the cell volume and RBC count exceeded the original values.

Yoshimura (124) stated that destruction of erythrocyte occurs during strenuous physical training and the normal value may be regained in course of time. Astrand (7) reported an increase in total hemoglobin and no change in hemoglobin concentration. Faulkner et al. (48) made a reference to the uncertainty of the effects of physical training on hemoglobin concentration, RBC count and hematocrit.

VIII. PULSE DECELERATION

VIII. a) Measurement

The H.R. increased by exercise begins to decelerate when exercise is discontinued. The time taken for recovery in relation to the exercise performed earlier, is an indication of the functional capacity of the cardiovascular system to regain normalcy. Montoye (87) stated that the measurement is a valuable index in assessing physical fitness.

The response of the heart to a shift from work to rest is spontaneous. Elbel and Holmer (46), and Herxheimer (57) observed that the pulse rate following moderately strenuous exercise decelerates fast during the first two minutes and thereafter, it is slower.

VIII. b) Effects of Physical Training

Brouha (24) studied the nature of pulse deceleration in physically trained individuals and concluded that the recovery is much

quicker in the trained state than in the untrained state. Andersen (5) made a comparison of post-exercise HR in sedentary and physically fit persons, and found that the sedentary persons had a much slower recovery.

IX. FLEXIBILITY

IX. a) Measurement

Different methods have been employed to determine an individual's flexibility. One of the tests that has been used to measure trunk flexion is the Wells Sit and Reach Test (118) which consists of sitting with legs straight, knees stretched, and reaching for the toes with the hands. Bates (14) reasoned that the use of a linear measure for an angular motion can be inaccurate.

Simri et al. (104) compared two methods of determining the forward flexion of the trunk and found the one based on Wells Sit and Reach Test more reliable. The forward flexion of the trunk has been adopted as a test item by the International Committee for the Standardization of Physical Fitness Tests (104).

IX. b) Effects of Physical Training

McCue (82) studied the influence of physical activities on certain aspects of flexibility in college students and found that those who engaged in exercise regularly were more flexible than others. The factor contributing to greater flexibility was observed to be the elasticity of connective tissues surrounding the joints. Buxton (26) reported from experimental observation that advancing age affects flexibility, and physical training is a practical measure to

counteract this tendency within reasonable limits.

X. DETRAINING

X. a) Measurement

Physiological measurements made after training has been discontinued for a specified period (following training for a specified period), would reflect on the detraining effect attributable to that period. Michael et al. (84) pointed out that although there are numerous reports in the literature concerning the effects of physical training on physiological variables, there is meagre information on detraining.

X. b) Effects of Detraining

Kendrick et al. (66) observed that 12 weeks of detraining following 20 weeks of training resulted in approximately a 50% reduction in the initial improvement in cardiovascular efficiency. Fardy (47) investigated the effects of a ten-week program of soccer training following 5 weeks of detraining. Detraining resulted in significant deterioration of fitness gains. There was a decline in the maximal O_2 consumption and an increase in HR at a given work load.

Cureton and Phillips (33) observed the changes in the cardio-respiratory system in a study involving 8 weeks of training followed by 8 weeks of rest, and in continuation, 8 weeks of training again. The retraining was of a higher intensity than the initial training. Training caused an increase of 35% in maximal O_2 consumption which returned to approximately the pre-training value after the 8 weeks of detraining. Following retraining, it increased 93% (from 25 to 48

ml/kg/min.) above the initial level. Considerable loss in body weight was observed when the final tests were administered.

CHAPTER III

METHODS AND PROCEDURES

SAMPLE

Fifty-one male undergraduates residing in the Lister Hall of the University of Alberta volunteered to be the subjects in this study. The age range of the subjects was 17 to 22, the mean age being 18.8 years.

The subjects first completed a questionnaire (Appendix A) issued to elicit information on their normal physical activities, the state of their general health, any medication used, etc. It was ascertained that the subjects were not participating in any serious physical training, were free from organic diseases, and were also not under any medication.

None of the subjects had previous training or experience in Yoga or 5BX. Seven of the subjects however, had TM training offered by the Maharishi International Acadamy, and had practiced meditation on their own.

ORIENTATION

Prior to the experiment, the training and testing procedures were explained in detail to the subjects to ensure proper understanding and helpful cooperation, so as to secure reliable data from the tests. Printed instructions (Appendix B) were also issued to strengthen the value of the orientation. Before the tests, the subjects were all given adequate time to observe and understand the

working of the apparatus used in the tests, all of which were fairly simple in operation and adjustment, and within the comprehension of the subjects. They were also provided with an opportunity for a trial participation in the test items.

The services of 3 experienced volunteer helpers familiar with similar work were utilized for administering the tests; and they were duly given the necessary instructions (Appendix B) well in advance.

TESTING SCHEDULE

The subjects were tested twice, first, just before the training and later, at the same time of the day, immediately following the training. The Yoga group subjects were, however, tested a third time, this third test being done following detraining. The tests on the metabolic cost of *Savasana* and TM were done only once on the subjects concerned following the retraining period.

To make a subjective analysis of the effects of training, the subjects of the Yoga and 5BX groups were asked to complete a questionnaire (Appendix A) at the conclusion of the six-week training.

INSTRUMENTS AND THEIR CALIBRATION

Instruments

The instruments used for testing included measuring tapes, weighing scales, stop watches, instrument for the Wells Test (81), oral clinical thermometers, Collins Standard Vitalometer, Monark Bicycle Ergometer, Sanborn 500 Electrocardiogram, Beckman Medical Gas Analyzer Model LB.1 (for CO_2) and Beckman Model 715 Process Oxygen Monitor of the Honeywell Electronic Medical System (60),

Parkinson-Cowan Volume Meter, Fisher Hemophotometer for hemoglobin measurement, Capillary tubes, Centrifuge and Micro Capillary Reader for hematocrit, Coulter Counter B for RBC count, and Thyopac-4 Kit for Assay of Thyroxine (3). All the instruments were calibrated and checked for precision at the beginning of the experiment and before each testing period.

Calibration

The bicycle ergometer was calibrated according to a standard procedure (62). The gas analyzers were calibrated each testing day with sample gases before the tests. The sample gases were checked with a Micro Scholander Apparatus according to a standard procedure (30). The correction factor for converting the gas volume to STPD was applied. The apparatus and instruments used for the blood tests were calibrated by a qualified medical laboratory technician according to routine methods of clinical investigation.

Accessories

The accessories pertaining to the instruments used for testing included surface electrodes, nose clamps, Collins Triple J Valves, rubber hoses, sterilized rubber mouth-pieces, Meteorological Balloons for collection of gas samples, regular and heparinized Vacutainer tubes, and disposable Vacutainer needles. All accessories were carefully checked to ensure accurate measurement. The Meteorological Balloons were periodically tested for leakage and diffusion to make sure that the gas analysis is exact.

HEIGHT AND WEIGHT MEASUREMENTS

The height and weight of each of the subjects were measured before the commencement of the experiment and during every subsequent testing period.

COLLECTION AND ANALYSIS OF GASES

Preparation of the Subjects

In order to establish the basal conditions needed for BMR measurements, the subjects were instructed to eat their supper by 5:00 P.M. the previous day, to refrain thereafter from eating or drinking anything except water until the test was taken and to have at least 8 hours of sleep. They were also advised to remain in bed and rest, and not to smoke in the morning before the test. Written instructions regarding preparation and the time of testing (Appendix B) were given to the subjects in advance before each test. The cooperation of student leaders in the Lister Hall was sought to remind the subjects of what was expected of them. To ensure the strict observance of instructions relating to the subjects' preparation for the tests, a check-list (Appendix B) was used during the test, and the subjects were encouraged to give truthful answers.

Gas Collection

Each subject was met in his bedroom at the appointed time between 6:00 A.M. and 7:30 A.M. An informal approach was made so as to enable the subject to relax. The temperature of the room which was controlled by a central heating device was maintained at 20°C.

A portable weighing scale was used to measure the weight of the subject dressed in underwear. He was then asked to lie down and relax. The HR was twice measured on the basis of the radial pulse, once immediately after relaxation and again after an interval of 5 minutes of continued rest and relaxation. In the case of a few, the interval was prolonged in order to facilitate accurate measurement. While the subject was thus resting, the oral temperature was taken. A rubber mouth-piece connected to a triple J valve was fitted into the mouth. One end of the valve-unit had its connection with a rubber hose which was fitted to a Meteorological Balloon through a 3-way valve.

To facilitate a proper and successful test, the subject was asked to breathe through the mouth for 1 minute, while the Balloon remained closed. Then,his nose was clamped with a nose clip as he continued breathing through the mouth for one more minute. Following that, the expired air was directed into the Balloon by opening the valve just before inspiration and using a stop watch, a five-minute sample was collected. During the gas collection, the RR was noted by observing the rise and fall of the chest for 2 minutes. After the gas collection, the HR was taken again to ascertain that the subject remained in the same state of relaxation.

The above procedure was repeated the following day under identical conditions. If, for some reason, one measurement was higher than the other, the lower one was taken as the true value.

Gas Analysis

The sample of expired gases was analyzed for their O_2 and CO_2 content, using the Honeywell Electronic Medical System at the Faculty of Physical Education of the University of Alberta. The volume was measured with the volume meter and it was corrected to STPD. The volume of air utilized for analysis, based on the duration of feeding in the sample and flow rate, was added to it. A desk computer (Olivetti 101) was pre-programed to reckon O_2 consumption per minute, expired TV and RQ.

To verify whether the subject was breathing normal atmospheric air while the sample of expired gases was collected, a sample of the room air was also collected and analyzed for its O_2 and CO_2 content.

BMR DETERMINATION

The DuBois (44) Formula was used to calculate the body surface area. The O_2 consumption per minute was converted into O_2 per hour per square meter of body surface, and the caloric value was determined as given by Knoebel (68). In the absence of local authoritative standards, the Robertson and Reid (99) Normal Standards of BMR were applied. The step-wise procedure is given in Appendix D. A pre-programed Olivetti 101 desk computer was used for correctness of the calculations.

BLOOD SAMPLING AND ANALYSIS

On one of the two test days, blood samples were taken by qualified medical technicians, after the collection of gas samples for the BMR test, and before breakfast. The samples were drawn from the

cubital vein into two Vacutainers, one of which contained heparin, an anti-coagulant.

The tube containing coagulated blood was then centrifuged and the serum carefully separated. All the serum specimens were frozen and were properly labelled and preserved until the detraining part of the study was over. To establish uniformity of measurement, the T-4 test on the serum was done all at one time, following the Thyopac-4 technique (3).

The blood specimens treated with the anti-coagulant were tested for hemoglobin, hematocrit and RBC count immediately after each day's collection. The tests were done according to standard laboratory procedures (27, 83) by qualified medical technicians at the local hospital.

TESTING CONDITIONS

Tests other than BMR and blood analysis were administered in a specially arranged room at the Lister Hall. The room had proper ventilation and its temperature was maintained at 20°C. The subjects were tested at a previously arranged time from 9:00 A.M. to 11:30 A.M., 2:00 P.M. to 4:30 P.M., and 7:00 P.M. to 9:30 P.M. The repetition of tests at different testing periods was done at the same time, under identical conditions.

PHYSICAL WORK CAPACITY TESTS

The test procedure was similar to the one used in a study of Canadian children (62) which was based on the method Sjostrand (105) introduced. Before administering the test, the subject's weight

was measured. The subject mounted a Monark Bicycle Ergometer and three electrodes were fixed appropriately to his chest and back. His initial HR was noted and reasonable time was allowed to establish a normal resting HR. The subject was required to pedal in cadence with a metronome set for 50 revolutions per minute and complete a twelve-minute bout consisting of 3 four-minute progressively increasing work loads, so adjusted as to induce a HR of about 170 during the third phase of the exercise. The HR was recorded with the help of a Sanborn Electrocardiogram.

The HR at the end of each four-minute period was plotted against work loads, and the work loads necessary to produce 170 and 130 beats per minute were determined. The predicted value of maximal O_2 consumption was calculated from the nomogram of Astrand and Ryhming (9). An APL Program was used for the computation of the PWC results.

VITAL CAPACITY

The subject was directed to forcefully inhale and exhale twice before taking the test as recommended by Mathews (81). Standing erect, and after a deep inhalation, the subject exhaled into a Collins Standard Vitalometer kept on a table.

CHEST EXPANSION

The chest circumference was measured in line with the nipples with a non-stretchable tape, with the subject standing and after a full expiration, and a second measurement was taken following full inspiration. Care was taken to see that the subject did not enlarge

the muscles of the chest or back during the measurement. The measurements were repeated once, and only the average values of the two were taken.

BREATH-HOLDING

Breath-holding without prior hyperventilation was timed with a stop watch, with the subject seated on the floor.

FLEXIBILITY

The Wells Sit and Reach Test was administered as given by Wells and Dillon (118). The zero line in the apparatus coincided with the near surface of the front board. The minus values were toward the subject and the plus values were further away. To enhance the reliability of this test, three preliminary bobs were permitted to each subject as advocated by Mathews (81).

HEART RATE DURING *SARVANGASANA*

The subject took up the inverted shoulder stand position of *Sarvangasana* and maintained it, and in this position the carotid pulse was taken after 2 minutes of reaching the correct position. The measurement was repeated on a subsequent day and the average value was taken.

MAXIMAL HEART RATE

The procedure of the Astrand Test of maximal O_2 consumption as modified by Macnab et al. (78) was used. The subject pedalled a Monark Bicycle Ergometer at a work load of 750 kpm/min. for 4 minutes and then rested for 5 minutes. The work rate was thereafter increased

by 150 kpm/min. and the subject pedalled for 4 minutes, followed by a rest period of 5 minutes. This procedure was continued until the HR did not register any further rise. Electrocardiograph recordings were used to determine the HR.

PULSE DECELERATION

After Exercise

The PWC test scores were used as the basis to determine the work load. A work load suitable to elicit a HR of about 130 was set, and the subject was asked to pedal a Monark Bicycle Ergometer for 3 minutes, at the end of which the work load was increased so as to raise the HR to about 180, for a further period of 3 minutes. At the end of the six-minute exercise bout, the HR was recorded with the ECG. The subject then rested his feet on the bar and sat quietly on the bicycle for 1 minute. The ECG connections were then removed and the pulse was taken for 30 seconds after the one-minute rest period.

In order to compare 3 methods of recovery, the above test was done on 3 days, and followed up in 3 different ways. In Method I, the subject sat on the bicycle for 3 minutes. In Method II, the subject pedalled for 3 minutes at one half the work load with which he started. In Method III, the subject gently moved to a high bench kept close to the bicycle and relaxed doing *Savasana* for 3 minutes. In all the 3 cases, the HR was recorded after the three-minute recovery period.

The interval between the one-minute recovery (sitting on the bicycle) and the three-minute recovery was kept constant at 60 seconds so as to provide time for shifting in Method III and to establish

uniformity. Each subject went through all the 3 methods, each method on a different day. To equalize practice effect, the order of participation in the 3 tests was assigned at random for each subject.

Relaxation

On arrival at the testing room, the pulse of the subject was taken in a sitting position. After 5 minutes of rest in the same position, a second reading of the pulse was taken. The subject then performed *Savasana* for 5 minutes, and a third reading was thereafter taken. The same test was administered to the Control subjects, for whom *Savasana* was substituted by rest in supine position.

METABOLIC COST OF *SAVASANA* AND TM

The tests were administered in the afternoon, between 4:00 and 6:00 P.M., before supper.

The subject was advised to wear comfortable clothing for the test. On arrival at the testing room, he was asked to sit on a chair (straight back) and rest. The equipment for the collection of expired gases (same as the one used for the BMR test in this study) was arranged without hindrance to the subject. After the mouth-piece was fitted, he was asked to breathe according to his convenience, either through the mouth or nose, while the Balloon remained closed. After 13 minutes, direction was given to breathe through the mouth for a minute. Then the nose clamp was put on, as the subject continued to breathe through the mouth for another minute, thus completing 15 minutes of habituation in a sitting position. Following this, a five-minute sample of expired gases was collected the same way it was done for the BMR test in this study.

A second five-minute sample of expired gases was collected after 15 minutes of the treatment, i.e. Yoga subjects doing *Savasana*, TM subjects doing meditation, and Control subjects resting in supine position. A verbal check was made at the end to ascertain that the subject was not asleep.

The procedure of gas analysis explained in the BMR test was adopted here also.

As the TM subjects were new to the experimental procedure, a practice session was arranged a week before the tests, each subject meditating for 15 minutes with the mouth-piece and nose clamp fitted on them.

ASSIGNING SUBJECTS TO TREATMENTS

Following the pre-training tests, the 44 subjects were classified into two categories based on their BMR scores as follows: (1) Above 0, and (2) Below 0. They were then evenly and randomly assigned to the 3 groups for treatments, namely, Yoga (T1), 5BX (T2) and Control (T4). Seven volunteers apart from the 44 subjects included in the study were assigned to TM (T3) only.

TREATMENTS

T1 = Yoga training, 4 days a week for 6 weeks.

T2 = 5BX training, 4 days a week for 6 weeks.

T3 = TM training followed by individual meditation.

T4 = Control treatment.

Yoga

Each training session consisted of the following pursued in the same order as given here: Quiet sitting for 1 min., *Bhujangasana* for 1 min., *Halasana* for 3 min., *Sarvangasana* for 6 min., *Matsyasana* for 2 min., *Savasana* for 3 min. and *Pranayama* for 2 min. The total time involved in doing the 5 *Asanas* was 15 minutes. The subjects were directed to concentrate on a single thought of their choice.

Bhujangasana, Halasana, Sarvangasana and *Matsyasana* were practiced as given by Govindarajulu (54), and *Savasana* was done according to the procedure advocated by Kuvalayananda (71). *Pranayama* was practiced in two parts, the first one being simple deep breathing through the nose without *Kumbhaka* (retention of breath) for 1 minute, and the other also simple deep breathing through the nose with a brief *Kumbhaka,* making *Rechaka* (exhalation) slightly longer than *Puraka* (inhalation) for 1 minute. Both methods of *Pranayama* were practiced as given by Majumdar (79). The training sessions were held at the Lister Hall in the mornings 4 days a week, on Mondays, Tuesdays, Thursdays and Fridays. The training lasted for 6 weeks.

At the conclusion of the training, the subjects were asked to refrain from practicing Yoga and maintain their usual normal life style for 6 weeks. Following this detraining period, 7 of the Yoga subjects volunteered to continue their training for further tests. They participated in a six-week training program identical to the one offered to them earlier.

5BX

The subjects were trained according to the 5BX Plan (102) 4 days a week (Mondays, Tuesdays, Thursdays and Fridays) for 6 weeks. To the 11 minutes of prescribed exercises, additional exercises for 4 minutes consisting of Stride Jump, Half knee Bend, Trunk Twist, and Leg Cycling (39) were added, thereby increasing the total time to 15 minutes in order to equalize the time devoted to 5BX and Yoga exercises during training.

The 6 progressive steps outlined in the 5BX Plan were introduced in the same sequence on a weekly basis. The progression was from Level D to Level A of each Chart, beginning with 1 and ending with 6. The exercises were performed to the cadence of a metronome pre-set to the required frequencies. The training sessions were held in the mornings at the Lister Hall.

Transcendental Meditation

The 7 volunteers, who already had gone through an orientation course in TM under a scheme promoted by the Maharishi International Acadamy (115), practiced meditation on their own. Their training consisted of 2 daily sessions of 15 to 20 minutes, 5 to 7 days a week. At the time of testing, their experience ranged from 8 to 12 weeks.

Control

The subjects were asked to maintain the same activity pattern and life style for 6 weeks. Seven among them who maintained the control state for a further period of 12 weeks were used as subjects in the tests to determine the effect of *Savasana* and TM on metabolic rate.

STATISTICAL TREATMENT

The statistical analyses to test the significance of differences between measurements were done as follows:

1) Effects of treatment (within group)

a) To test the significance of differences between pre-training and post-training estimates (Yoga Pre-trg. vs. Yoga Post-trg., 5BX Pre-trg. vs. 5BX Post-trg. and Control Pre-trg. vs. Control Post-trg.) a One-way Analysis of Variance for Correlated Samples as given by Winer (120) was applied.

b) To test the significance of differences between the post-training and post-detraining estimates (Yoga Post.trg. vs. Yoga Post-detrg.) a One-way Analysis of Variance for Correlated Samples (120) was applied.

c) To test the significance of differences between the pre-treatment and post-treatment estimates in the tests on the metabolic cost of *Savasana* and Transcendental Meditation (Yoga Pre-treat. vs. Yoga Post-treat., TM Pre-treat. vs. TM Post-treat. and Control Pre-treat. vs. Control Post. treat.) a One-way Analysis of Variance for Correlated Samples (120) was applied.

2) Comparison of treatments (between groups)

a) To test the significance of differences between treatments in the main part of the study (Yoga vs. Control, Yoga vs. 5BX, and 5BX vs. Control) a One-way Analysis of Covariance with Scheffe multiple comparisons (120) was applied.

b) To test the significanace of differences between treatments in the tests on the metabolic cost of *Savasana* and Transcendental Meditation (Yoga vs. Control, Yoga vs. TM, and TM vs. Control) a One-way Analysis of Covariance with Scheffe multiple comparisons (120) was applied.

3) Comparison of treatments (within group)

To test the significance of differences of the three pulse deceleration (after exercise) methods (Yoga group: Sitting, Mild Exercise and *Savasana*), a One-way Analysis of Variance - Repeated Measures for Correlated Samples, followed by a Correlated t test, to determine differences between treatments as given by Winer (120) was applied.

4) Comparison of estimates on single variables (within group and between group)

To test the significance of other measurements not covered by the above, Correlated t tests-same sample and Uncorrelated t tests-different samples (120) were used.

Significance Level

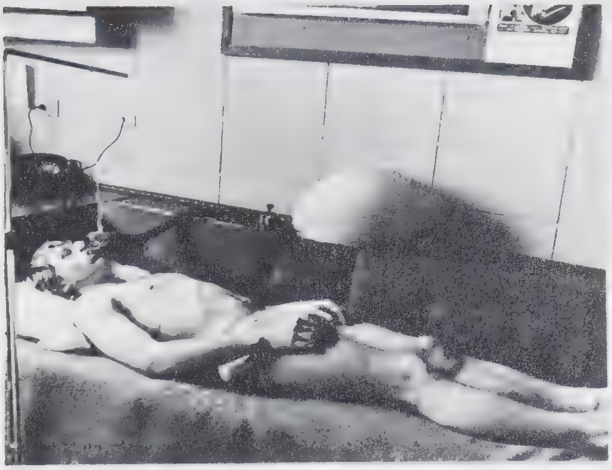
The level of significance established to test the differences was .05 ($p < .05$). The statistical analyses and computations were done with the IBM 360 Computer System at the University of Alberta.

Table I

Training and Testing Schedule

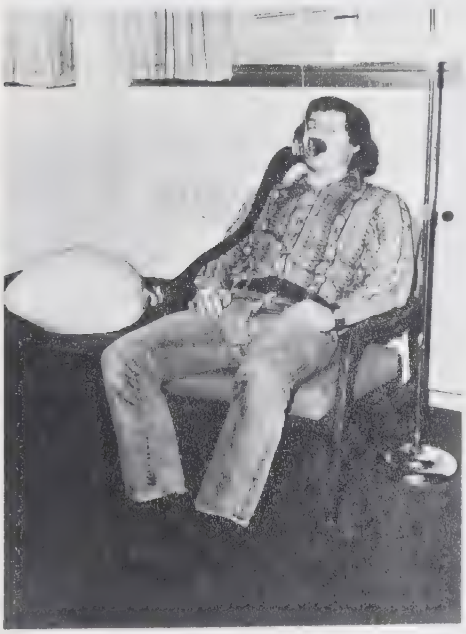
Groups	Pre-trg. Tests	Post-trg. Tests	Post-detrg. Tests	Post-retrg. Tests	
				Metabolic Rate N = 7 Control Measurements	Metabolic Rate N = 7 Expl. Measurements
T1 Yoga N = 15	BMR, PWC, Max. O_2, Hemo., Hemat., RBC, T-4, Flexi., Vit. Cap., Chest Ex., Br.-hold., Max. HR & Pul. Decl.	BMR, PWC, Max. O_2, Hemo., Hemat., RBC, T-4, Flexi., Vit. Cap., Chest Ex., Br.-hold., Max. HR & Pul. Decl.	BMR, PWC, Max. O_2, Hemo., Hemat., RBC, T-4, Flexi., Vit. Cap., Chest Ex. & Br.-hold.	Metabolic Rate N = 7 Control Measurements	Expl. Measurements
T2 5BX N = 15	BMR, PWC, Max. O_2, Hemo., Hemat., RBC, T-4, Flexi., Vit. Cap., Chest Ex. & Br.-hold.	BMR, PWC, Max. O_2, Hemo., Hemat., RBC, T-4, Flex., Vit. Cap., Chest Ex. & Br.-hold.	x x x	x x x	
T3 TM	x x x	x x x	x x x	Metabolic Rate N = 7 Control Measurements	Expl. Measurements
T4 Control N = 14	BMR, PWC, Max. O_2, Hemo., Hemat., RBC, T-4, Flexi., Vit. Cap., Chest Ex. & Br.-hold.	BMR, PWC, Max. O_2, Hemo., Hemat., RBC, T-4, Flexi., Vit. Cap., Chest Ex. & Br.-hold.	x x x	Metabolic Rate N = 7 Control Measurements	Expl. Measurements

COLLECTION OF SAMPLES FOR TESTS

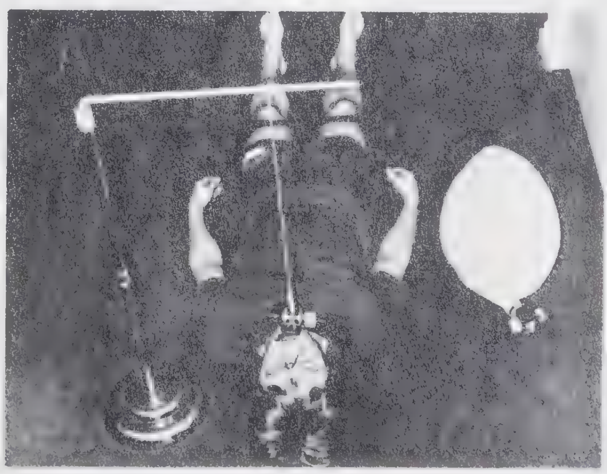


1. Basal Metabolic Rate

2. Blood Analysis

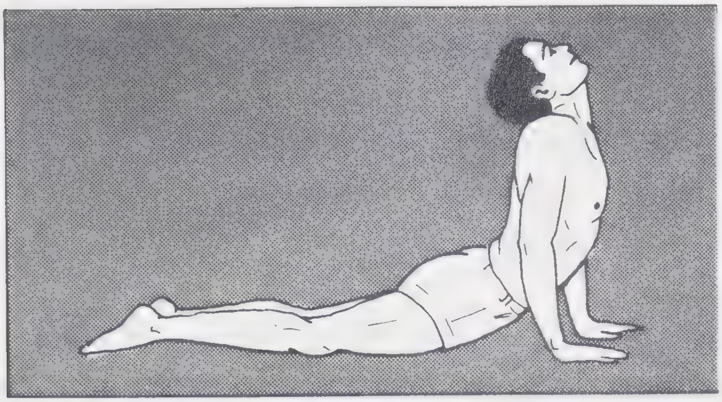


3. Metabolic Rate - TM

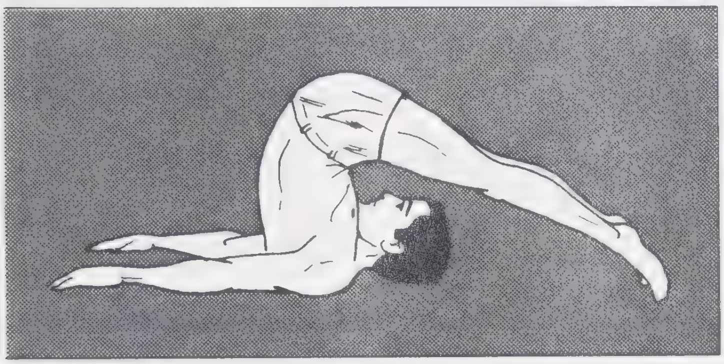


4. Metabolic Rate - *Savasana*

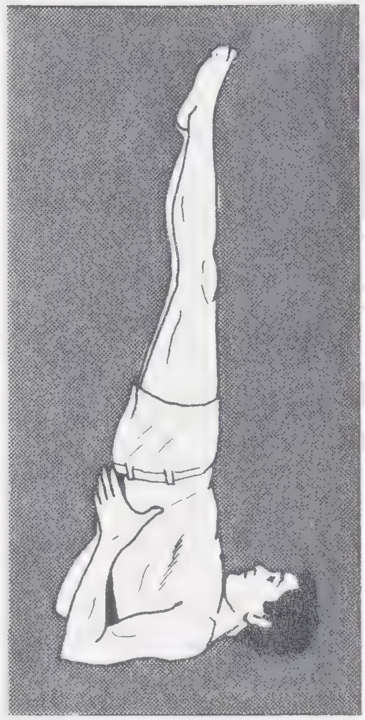
PLATES 1 to 4



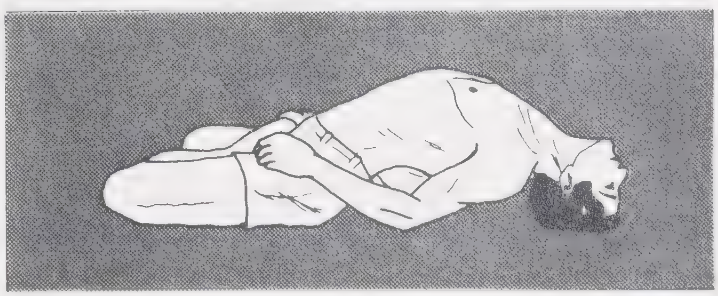
5. *Bhujangasana*



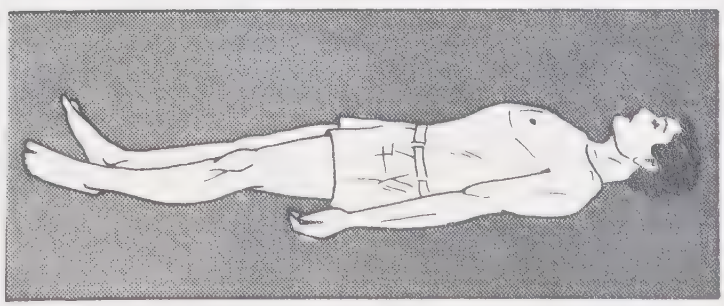
6. *Halasana*



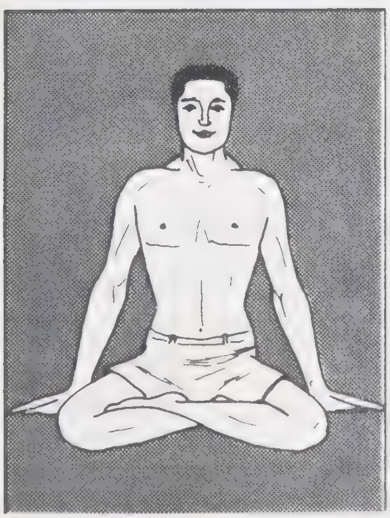
7. *Sarvangasana*



8. *Matsyasana*



9. *Savasana*



10. *Pranayama*

PLATES 5 to 10

CHAPTER IV

RESULTS AND DISCUSSION

RESULTS

The investigator obtained the following results through the studies made in the course of this research with four groups indicated here as T1 (Yoga), T2 (5BX), T3 (TM) and T4 (Control).

AGE

The mean age of the subjects was 18.8 years, the range being 17 to 22.

ANTHROPOMETRIC MEASUREMENTS

The mean values of height, weight and body surface area are given in Table II.

Table II

Height, Weight and Body Surface Area

Group & Treat.		Height (cm.)	Weight (kg.)	B. Surf. (sq. m.)
T1	Pre-trg.	173.2	72.1	1.84
	Post-trg.	173.2	72.5	1.86
	Post-detrg.	173.2	73.9	1.87
T2	Pre-trg.	174.4	74.2	1.88
	Post-trg.	174.4	74.3	1.89
T4	Pre-trg.	172.4	70.7	1.82
	Post-trg.	172.4	71.1	1.83

The height, weight and body surface measurements of T3 group were 171.4, 70.3 and 1.80 respectively.

BASAL METABOLIC RATE

The BMR of the T1 group increased from the pre-trg. value of -0.26% to 5.33% after training. This difference was statistically significant. The differences between T1 and T2, and T1 and T4 were also significant. The other comparisons did not indicate any significant change. A summary of the mean values (percentage deviation from the normal standards) is given in Table III.

Table III

Basal Metabolic Rate

Treat.	T1	T2	T4
Pre-trg.	-0.26%	-0.78%	+0.67%
Post-trg.	+5.33%	-1.02%	+0.90%
Post-detrg.	+4.34%	-	-

It was found that 18.2% of the subjects had slightly lower values of BMR in the second pre-trg. tests, and 9.8% of them had lower values in the second post-trg. tests.

MEASUREMENTS COMPLEMENTARY TO BMR

The results of the tests (mean values) on BT, HR, RR, TV, and RQ are given in Table IV.

Table IV

Body Temperature, Heart Rate, Respiratory Rate, Tidal Volume and Respiratory Quotient

Group & Treat.		BT (°C)	HR (per min.)	RR (per min.)	TV (ml.)	RQ (ratio)
T1	Pre-trg.	35.6	56.7	11.3	454	0.82
	Post-trg.	35.9	53.6	10.1	477	0.81
	Post-detrg.	35.6	54.3	9.8	487	0.83
T2	Pre-trg.	35.7	55.8	11.6	450	0.81
	Post-trg.	35.8	52.2	10.5	455	0.82
T4	Pre-trg.	35.9	54.7	10.7	464	0.84
	Post-trg.	35.7	55.6	11.1	460	0.82

The differences between pre-trg. and post-trg. values in HR, RR, and TV of T1 group, and in HR and RR of T2 group were statistically significant. The other comparisons did not indicate any significant changes.

BMR MULTIPLE

The BMR Multiple (Kcal/sq.m/hr. in maximal work ÷ Kcal/sq.m/hr. in basal state) which expresses the range of energy expenditure of each group was recorded as follows:

T1: Pre-trg. = 13.7, Post-trg. = 13.1; T2: Pre-trg. = 12.6, Post-trg. = 14.4; T4: Pre-trg. = 13.2, Post-trg. = 13.0.

BLOOD TESTS

T-4 Test for Thyroxine

The pre-trg. and post-trg. test results showed an increase from 5.2 to 6.2 μgm/100 ml. in thyroxine of the T1 group, which was

statistically significant. The differences between T1 and T2, and T1 and T4 groups were also significant. The other comparisons did not indicate any significant differences. The results of the tests (mean values) on T-4, hemoglobin, hematocrit and RBC count are given in Table V.

Table V

T-4, Hemoglobin, Hematocrit and RBC Count

Group & Treat.		T-4 μgm/100 ml.	Hemo. (gm/100 ml.)	Hemat. (%)	RBC (mil/c. mm.)
T1	Pre-trg.	5.2	15.8	45.9	5.4
	Post-trg.	6.2	16.9	47.5	5.9
	Post-detrg.	5.9	16.6	48.1	6.1
T2	Pre-trg.	5.5	16.3	50.4	5.5
	Post-trg.	5.4	16.5	49.4	5.4
T4	Pre-trg.	4.9	14.9	46.1	4.9
	Post-trg.	4.7	15.1	47.0	5.2

The differences in the pre-trg. and post-trg. test scores in hemoglobin, hematocrit and RBC count of T1 group were statistically significant. The other comparisons did not indicate any significant differences.

PHYSICAL WORK CAPACITY AND MAXIMAL O_2 CONSUMPTION

The mean values of PWC_{170}, PWC_{130} calculated from the raw scores of PWC_{170}, and maximal O_2 consumption predicted from PWC_{170} are given in Table VI.

Table VI

PWC_{170}, PWC_{130} and Maximal Oxygen Consumption

Group & Treat.		PWC_{170} (kpm/min.)	PWC_{130} (kpm/min.)	Max O_2 (lit/min.)
T1	Pre-trg.	1244	549	3.47
	Post-trg.	1260	640	3.56
	Post-detrg.	1251	564	3.51
T2	Pre-trg.	1161	479	3.26
	Post-trg.	1333	582	3.71
T4	Pre-trg.	1193	537	3.35
	Post-trg.	1182	540	3.33

The differences in PWC_{170} between pre-trg. and post-trg. of T2 group; T2 and T1, and T2 and T4 were statistically significant. The differences in PWC_{130} between pre-trg. and post-trg. of T1, and post-trg. and post-detrg. of T1 were significant. The difference between pre-trg. and post-trg. of T2 was also significant. While the effects in T1 and T4 groups, and in T2 and T4 were significantly different, no other comparison indicated any significant difference. The increase in maximal O_2 consumption of T2 observed after training was statistically significant. The differences between T2 and T1, and T2 and T4 were also significant. The other comparisons did not indicate any significant differences.

The values of PWC_{170}, PWC_{130} and maximal O_2 consumption per kilogram of body weight indicated similar differences. A summary of the results is given in Appendix F.

RESPIRATORY MEASURES

The mean values of the test scores on vital capacity, chest expansion and breath-holding are given in Table VII.

Table VII

Vital Capacity, Chest Expansion and Breath-holding

Group & Treat.		Vit. Cap. (lit.)	Chest Ex. (cm.)	Br.-hold (sec.)
T1	Pre-trg.	4.3	5.6	53.9
	Post-trg.	4.8	7.4	66.1
	Post-detrg.	4.8	7.3	57.4
T2	Pre-trg.	4.5	5.5	49.9
	Post-trg.	4.9	6.5	53.6
T4	Pre-trg.	4.5	5.9	56.4
	Post-trg.	4.6	6.0	58.9

The differences between pre-trg. and post-trg. values in vital capacity, chest expansion and breath-holding of T1 group and T2 group were statistically significant. The differences between the post-trg. values of T1 and T4, and T2 and T4 in vital capacity; T1 and T4,and T2 and T4 in chest expansion; and T1 and T2,and T1 and T4 in breath-holding were found significant. The comparison of post-trg. and post-detrg. values in breath-holding of T1 group showed a significant drop. The other comparisons in the three parameters did not indicate any significant change.

FLEXIBILITY

The flexibility value of T1 group increased from (pre-trg.) 4.4 to (post-trg.) 11.3 cm. and then decreased to (post-detrg.) 6.0. The differences between pre-trg. and post-trg.,and post-trg.,and post-detrg. were statistically significant. The differences between the pre-trg. (6.5) and post-trg. (10.7) values of T2 was also significant. Significant differences were also found between T1 and T2, T2 and T4, and T1 and T4. The other comparisons did not indicate any significant differences. The summarised values are given in Table VIII.

Table VIII

Flexibility

Treat.	T1	T2	T4
Pre-trg.	4.4 cm.	6.5 cm.	4.9 cm.
Post-trg.	11.3 cm.	10.7 cm.	5.1 cm.
Post-detrg.	6.0 cm.		

MAXIMAL HEART RATE

The pre-trg. maximal HR of T1 group was 198.6 and it decreased to 196.2 after training. This difference was not statistically significant.

HEART RATE DURING *SARVANGASANA*

The mean HR of T1 group, measured after training was 84.6 (range of 76-93). This amounted to 31.0 beats per minute above their resting HR (measured in the basal state) and 111.6 beats below their maximum.

PULSE DECELERATION

The mean values of pulse deceleration following exercise are given in Table IX.

Table IX

Comparison of Three Methods: T1 Group

	I. Sit. HR (per min.)	II Mild Ex. HR (per min.)	III *Savas.* HR (per min.)
After Exercise	181	186	184
After 1 min. Sit.	129	131	130
After 3 min. Treat.	112	109	101
Drop in HR Sit. and Treat.	17	22	29

The differences in the drop in HR between Methods I and II, II and III, and III and I were statistically significant.

The mean values of pulse deceleration (not involving exercise) are given in Table X.

Table X

Supine Rest and *Savasana*

	Group & Treat.	Pre-trg. HR (per min.)	Post-trg. HR (per min.)
T1	5 min. Sit.	72.6	74.0
	5 min. Supine/*Savas.*	68.0	60.1
	Difference	4.6	13.9
T4	5 min. Sit.	-	75.6
	5 min. Supine	-	67.1
	Difference	-	8.5

The difference between the pre-trg. and post-trg. values of T1 group was statistically significant. The comparison of the post-trg. values of T1 and T4 was also significant.

METABOLIC COST OF *SAVASANA*, TRANSCENDENTAL MEDITATION AND SUPINE REST

The mean values of O_2 consumption determined before and during the treatments are given in Table XI.

Table XI

Oxygen Consumption

Group	Pre-treat. (ml/min.)	Post-treat. (ml/min.)	% Drop
T1	269.6	241.9	10.3
T3	257.0	216.9	15.5
T4	275.0	265.3	3.5

The pre-treat. and post-treat. difference in each group was statistically significant. The post-treat. comparisons of T1 and T3, T1 and T4, and T3 and T4 were also significant.

The mean values of the measurements complementary to O_2 consumption in the tests on metabolic rate are given in Table XII.

The differences between the values of pre-treat. and post-treat. in HR, RR and TV of the three groups were significantly different. The post-treat. differences in TV between T1 and T4, and T3 and T4 were also significant. The other comparisons did not indicate any significant differences.

Table XII

Heart Rate, Respiratory Rate, Tidal Volume and Respiratory Quotient

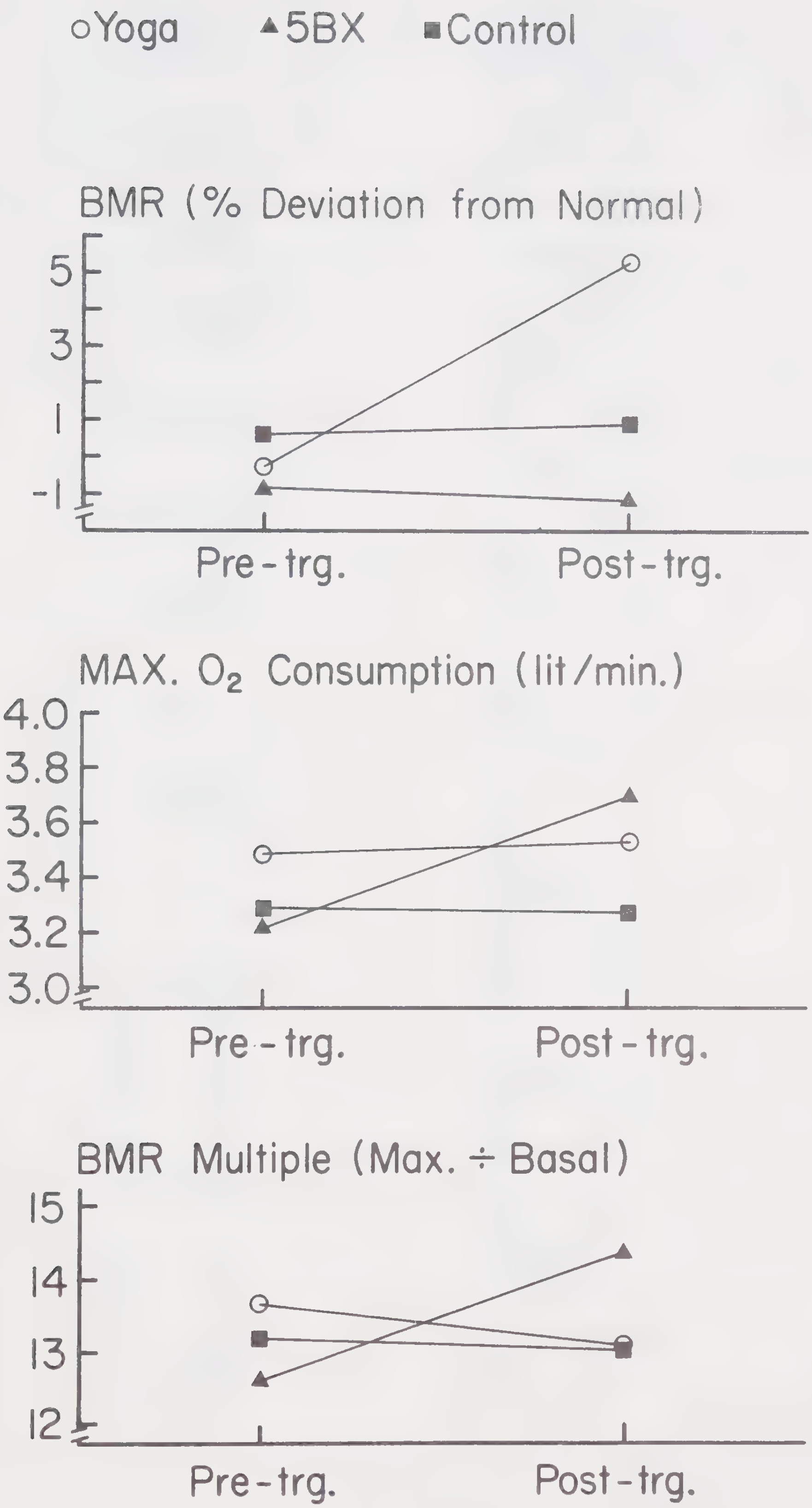
Group & Treat.		HR (per min.)	RR (per min.)	TV (ml.)	RQ (ratio)
T1	Pre-treat.	72.5	12.1	498	0.85
	Post-treat.	62.0	9.6	454	0.86
T3	Pre-treat.	70.0	10.7	500	0.85
	Post-treat.	64.3	8.1	444	0.85
T4	Pre-treat.	73.1	12.6	439	0.85
	Post-treat.	68.9	11.0	494	0.84

RESULTS OF HYPOTHESES TESTED

Based on the findings of this research, the null hypotheses of the three principal problems were rejected, to imply that (1) Yoga causes an increase in BMR, while 5BX and Control treatments have no effect on it, (2) 5BX improves maximal O_2 consumption, while Yoga and Control treatments have no effect on it, and (3) the metabolic cost of TM is lower than that of *Savasana*.

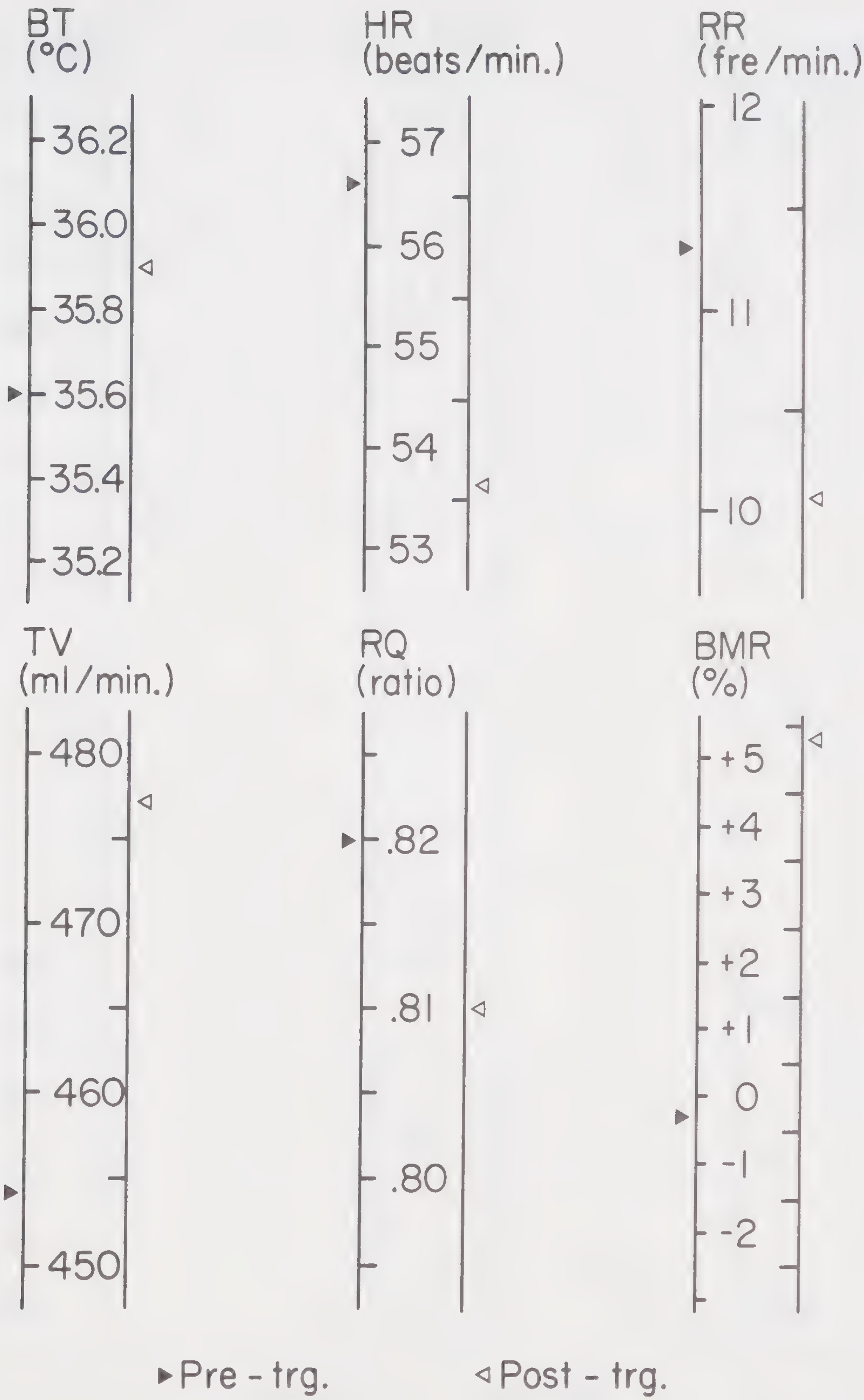
QUESTIONNAIRE

All the subjects of T1 and T2 groups reported that their health had improved after training. All T1 subjects and 38.5% of T2 subjects reported that they felt euphoric and more relaxed after training.



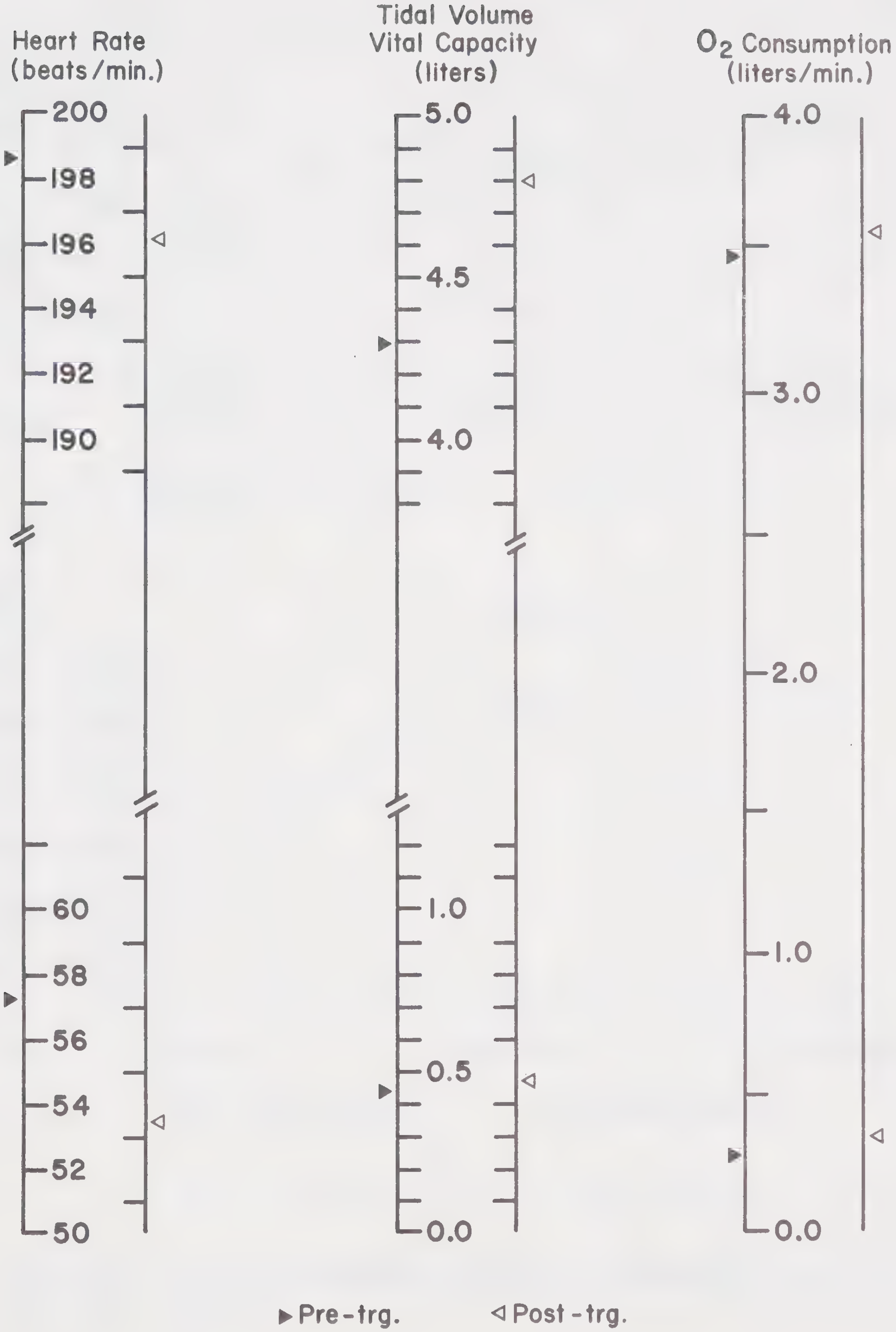
Effects of six weeks Yoga and 5BX training on BMR, Maximal O_2 consumption, and BMR Multiple.

Fig. 1

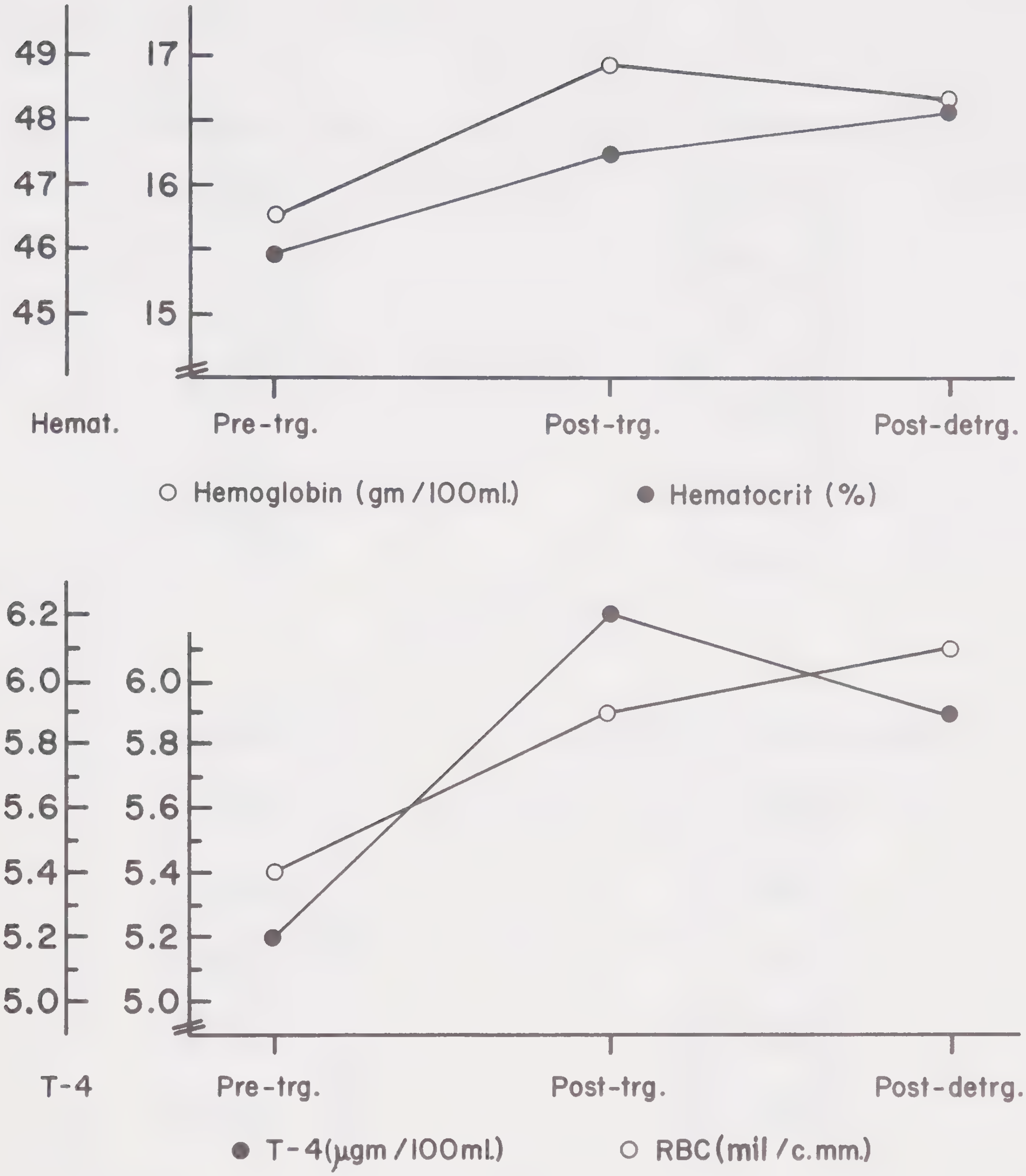


Basal measurements on BT, HR, RR, TV, RQ and BMR before and after six weeks of Yoga training.

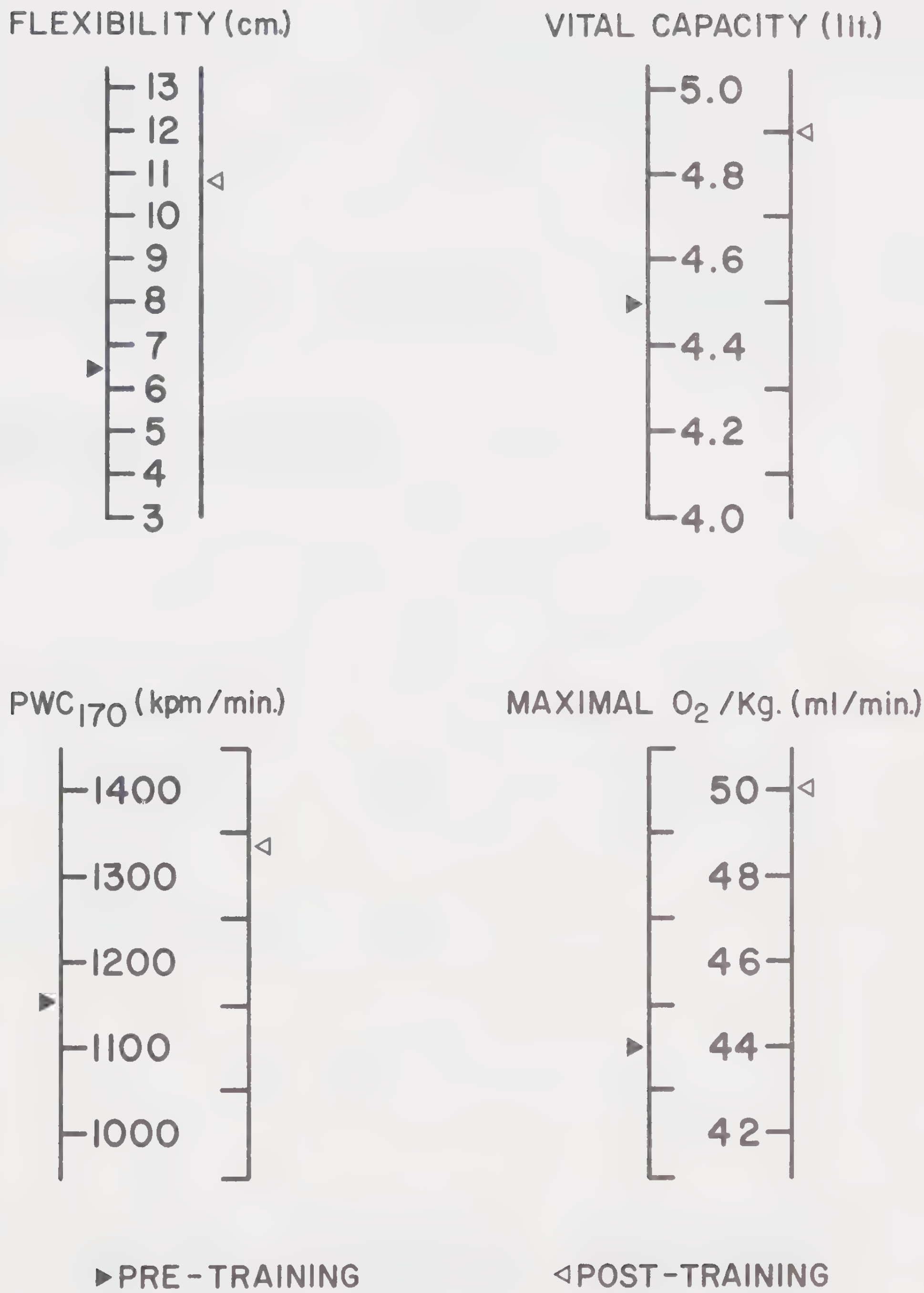
Fig. 2



Basal and maximal values of heart rate, O_2 consumption, and expired volume before and after six weeks of Yoga training.
Fig. 3

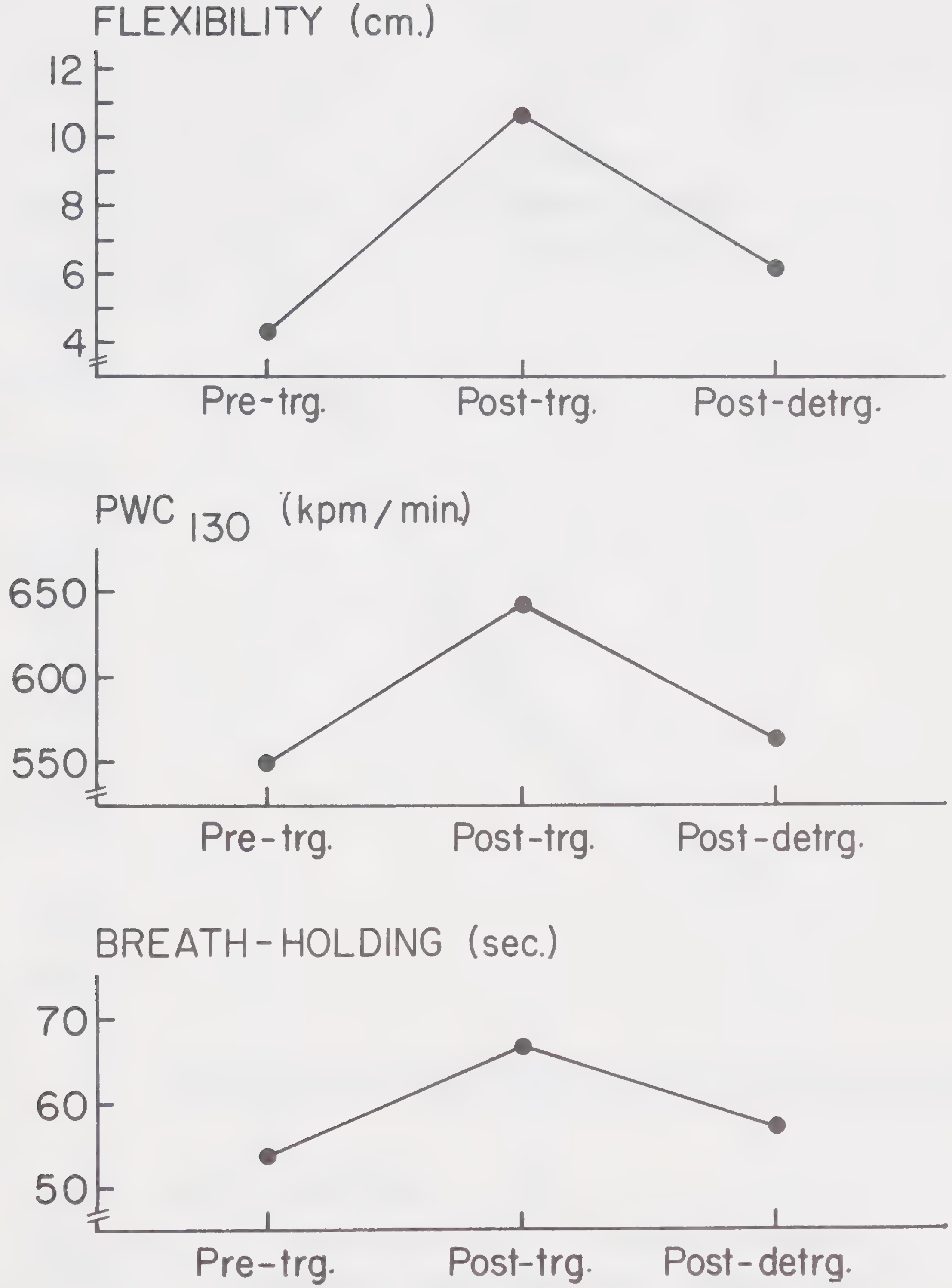


Effects of Yoga training and detraining on hemoglobin, hematocrit, RBC, and T-4.
Fig. 4

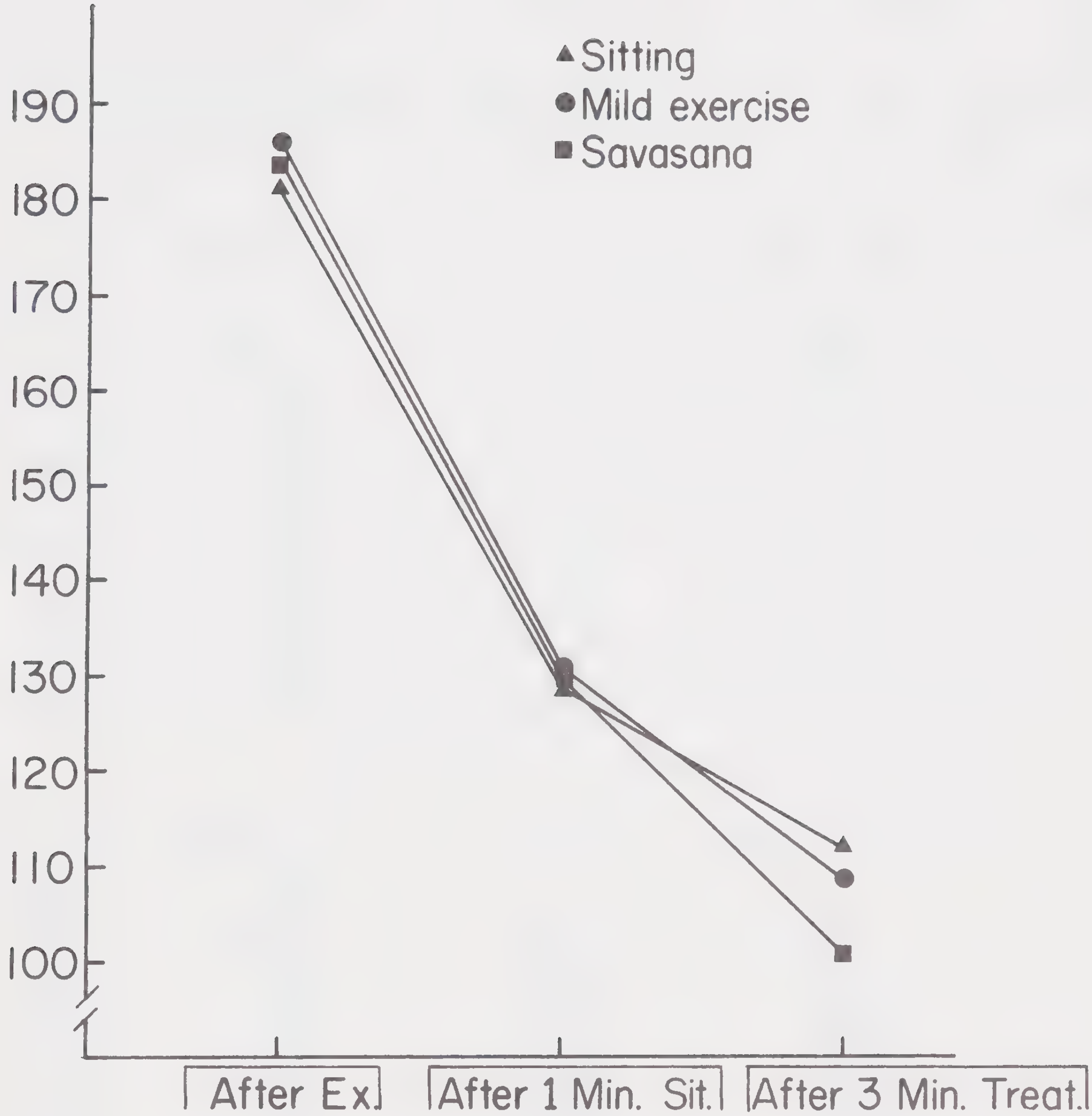


Effects of six weeks 5BX training on Flexibility, Vital capacity, PWC_{170}, and Maximal O_2 consumption per kilogram of body weight.

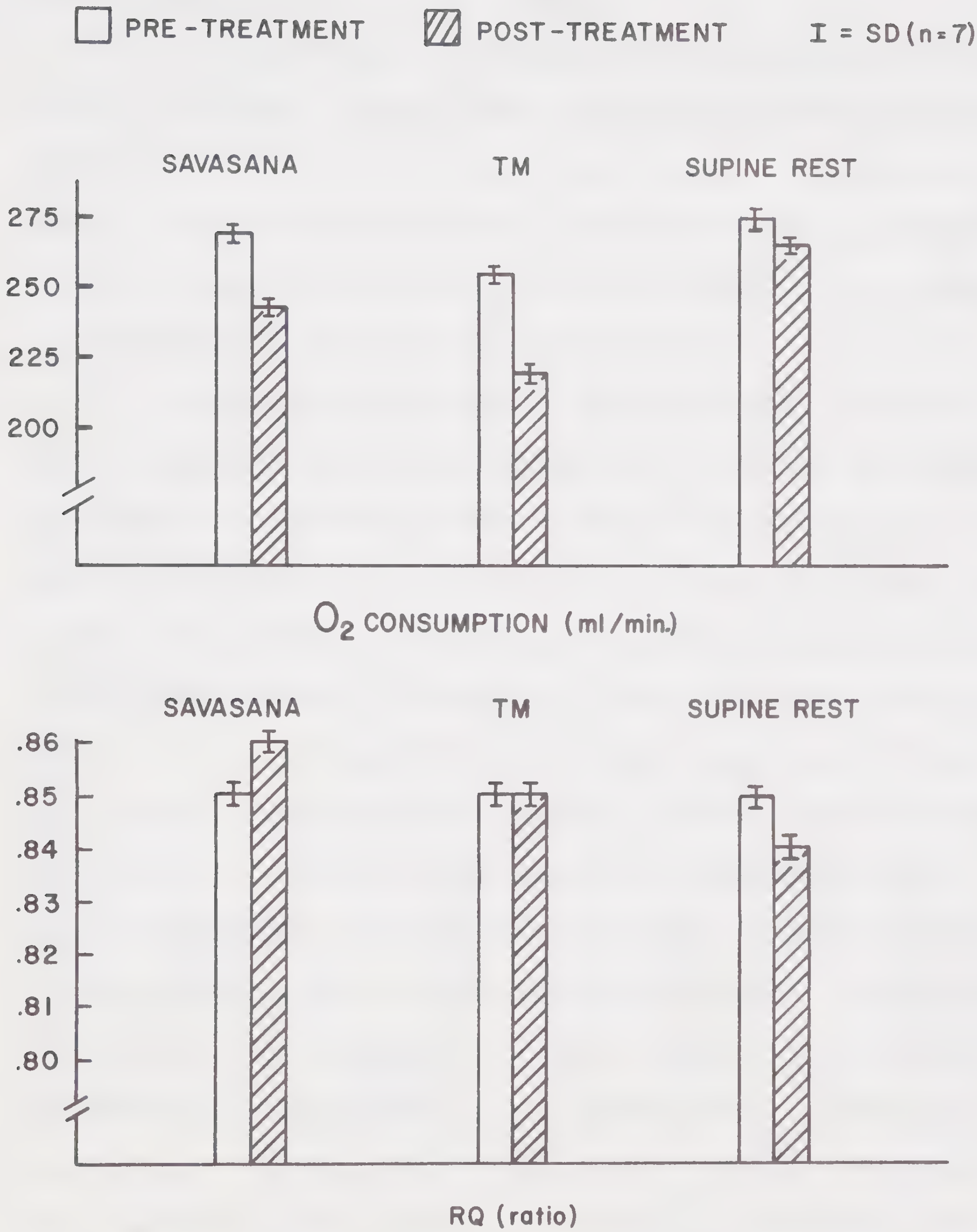
Fig. 5



Effects of discontinuing Yoga training for six weeks on Flexibility, PWC_{130}, and Breath-holding.
Fig. 6



PULSE DECELERATION
Comparison of three methods of recovery following exercise – Post-training measurements – Yoga group
Heart Rate (beats/min.)
Fig. 7



Metabolic cost of Savasana, TM, and supine rest.
Fig. 8

DISCUSSION

BASAL METABOLIC RATE AND THYROID FUNCTION

An increase in BMR was noticed in the Yoga group after six weeks of training. The main factor responsible for the increased BMR was the heightened activity of the thyroid gland. A significant increase in thyroxine as determined by the T-4 test was also observed in the Yoga group. It is possible that the thyroid was stimulated by a combination of a few functional changes.

Firstly, the thyroid is a vascular organ and it is likely that it receives a more abundant blood supply caused by the inversion and retention of the body position in *Asanas* like *Sarvangasana*. Secondly, by the same token, the hypothalamus and anterior pituitary may receive a larger supply of arterial blood, thereby perhaps assisting in the larger secretion of thyrotropin, the thyroid stimulating hormone. Thirdly, the thyroid being both under chemical and nervous control, mental concentration as in Yoga may influence the secretion of the thyroxine. Fourthly, it may be surmised that changes arise in cellular metabolism from the stimulation caused by thyroid hormones on the respiratory enzyme systems of the mitochondria. These changes, if they do occur, are possibly induced by improved microcirculation, an important effect claimed for Yoga training (112). Finally, the popular theory that the Chin-lock stimulates the thyroid seems to have some bearing. The compression in the region where the thyroid is located caused by postures such as *Sarvangasana* and *Halasana*, may squeeze out any hormone stagnating within the vesicles of the thyroid

gland, although a free outward flow is restricted by the absence of ducts. The removal of the hormone from the follicles may be facilitated by hydrolysis of the colloid by a proteolytic enzyme. It is uncertain that the Chin-lock can directly initiate such a chemical action. Furthermore, it is unlikely that any significant stimulation will follow merely due to mechanical influence.

In Yoga training, it is generally the practice to arrange the Asanas in sequence to have *Matsyasana* after *Sarvangasana* and *Halasana*, as it was done in this study. The posterior flexion of the neck involved in *Matsyasana* typifies an action opposite the Chin-lock, and the posture as a whole stabilizes hydrostatic pressure. Consequently, the arterial blood supply to the upper regions of the body and venous return from the lower regions speeded up earlier by *Sarvangasana* and *Halasana* return nearly to a normal level. The effects of such changes on the thyroid gland cannot be ascertained without further investigation.

The reports of the Yoga Research Institute at Lonavla claiming that Yoga stimulates the thyroid gland has been challenged by Govindarajulu (53), on the basis of a possible danger to the hormonal balance in the body. It is reasonable to place doubts on the usefulness of Yoga, if the so-called stimulation is likely to be extended to the point of hyperthyrodism.

It would appear that the feed-back mechanism plays a key role in checking untoward activities of the thyroid. In discussing endocrine physiology, Catt (28) pointed out that the negative feed-back is clearly a common control mechanism for hormone secretion,

particularly in the production of pituitary tropic hormones in response to peripheral hormone levels.

It is likely then, when thyroxine content tends to go beyond a certain threshold level, the situation is monitored to the hypothalamus and the pituitary depresses the secretion of further thyrotropin. The observation in this study was that the young men who practiced Yoga for six weeks had higher BMR within the normal range, and detraining did not cause any further change.

The BMR standard not being the same for all populations, it is necessary to consider here whether the subjects were from a normal population as determined by the particular standard applied. According to Guyton (56) 85% of the people fall within the limits of the appropriate standard. In this study, out of 44 subjects, three were outside the normal range at the commencement of the experiment, and two, at the end of the experiment.

Those subjects who had a higher BMR (near the upper limit) initially, showed a reduction in their values at the end of training. Such an action was perhaps caused by a positive feed-back mechanism. However, the number of such subjects being small, no safe conclusion could be drawn regarding the effect of Yoga in reducing BMR.

Increased BMR signifies enhanced cellular metabolism and it is perhaps an indication of better interaction between the thyroid hormone and the responsive cells or the presence of more active protoplasm. The physiological advantage of such increased energy expenditure to maintain vital functions in the basal state cannot be reckoned in terms of economy of O_2 cost and heat production. Nevertheless,

the heightened activity of the thyroid can provide zest and energy to a person at work and create euphoric feeling.

For centuries, Yoga teachers have advocated *Hatha* Yoga as a practical way of regaining youthfulness. It is doubtful that they ever thought of the effect of Yoga on BMR. However, it is a scientific fact that as a person grows older, the BMR diminishes gradually and an increase in BMR, while the age is constant, may be a sign of revival. Under the present circumstances, such a claim can only be accepted as a hypothesis, until convincing evidences are available.

The findings of this study, wherein the subjects had a higher BMR within the normal range, are in conformity with the work of Rangan (94). It follows, therefore, that the state of euthyroidism has not been upset by the influence of Yoga.

It would appear that *Asanas* have a scientific basis in regard to thyroid functions. The originators of Yoga probably suspected or experienced the adverse effects of hypersecretions due to faulty practices, and subsequently established possible controls. Govindarajulu (55) suggested that the purpose of the Chin-lock in *Sarvangasana* and *Halasana* is probably to place a check on overactivity of the thyroid. To establish the truth of this supposition, research to compare the effects of *Asanas* classified into categories would be necessary.

The studies so far made on Yoga seem to deal with the hormonal effects of Yogic *Asanas* only in relation to the thyroid. This is possibly due to insufficient information on the endocrines available to the earlier investigators. With the elaborate studies of the

endocrine glands, the present-day researcher in Yoga will do well to consider the influence of static exercises and concentration on the whole endocrine system. There is some evidence that the andrenocortical activity is enhanced through Yoga training (112). To add to such knowledge, a study of the effects of Yoga on the parathyroids should perhaps receive priority. Inasmuch as these glands are embeded in the thyroid, they are likely to be nourished the same way like the thyroid with more fresh blood during *Asanas* like the *Sarvangasana*. It may be hypothesized that increased production of parathormone partly accounts for the decreased nervous excitability seen in experienced Yoga Practitioners.

Following the period of detraining in this study no appreciable change was observed in the increased BMR or T-4, indicating the residual effect of Yoga training. There is reason to assume that the effects of the exercises began to unfold towards the latter part of training and therefore, such effects were sustained for a further period after training. However, it was not within the scope of this study to ascertain the time at which the physiological effects first began to take shape.

As regards the measurement, it was observed that some of the subjects (all three groups) had a lower BMR when the test was repeated on the second day. The subjects concerned indicated that they had slept less than 6 hours on the night prior to the first test. Inasmuch as they satisfied the other conditions of the basal state, it may be concluded that the increase in metabolic activity was associated with inadequate rest.

BMR Multiple

The BMR Multiple value in T1 group decreased after training owing to the increase in BMR. The value in T2 increased owing to the increase in maximal O_2 consumption. The BMR Multiple being greater in T2 (14.4) than in T1 and T4 (13.1 and 13.0) is an indication that 5BX had set a higher limit of cardiovascular and respiratory capacities.

MEASUREMENTS COMPLEMENTARY TO BMR

In this study, the measurements on BT, HR, RR, TV and RQ were made simultaneously when samples of expired air were collected for BMR assessment; and the records so taken accordingly reflect physiological conditions applicable to the basal state.

1. Body Temperature

The BT of a healthy person in the basal state is said to be slightly below the normal value, and individual differences in this regard are confined to a narrow margin (56). A similar observation (mean = 35.7; range = 35.4 to 36.2°C) was obtained in this study, and the final results indicated that the treatments had no effect on BT.

2. Heart Rate

It is now generally known that athletes have a lower resting HR than others of the same age and sex (8). In this study, the HR of both the Yoga and 5BX groups was found to be significantly reduced after training. This is in conformity with the results reported in the studies of Steadward and Singh (107), Steinhaus (109) and Udupa et al. (112).

It is a fair assumption that a slower HR accompanies a relatively larger stroke volume, so as to maintain a certain level of cardiac output. This, from the energy expenditure standpoint may be interpreted as an economical adaptation, involving less work for the cardiac muscles, while at the same time, the heart meets the normal demands of blood supply. The underlying cause and origin of such HR are by no means quite clear.

It is generally claimed that the ability of the heart to adapt its rate and output to altered conditions depends upon the properties of the neuromuscular system of the heart. According to Tipton et al. (111), the reduced heart rate is brought about by an increased vagal discharge. In animal experiments, an increase has been observed in arterial acetylcholine which has the property of depressing blood pressure and the general action of the heart. Whether or not such changes would occur in the human heart is a question which remains to be settled by further research.

3. Respiratory Rate and Tidal Volume

The RR of the Yoga and 5BX groups were found significantly decreased after training. The TV of both groups increased, although the change seen in the 5BX group was not statistically significant. It is the contention of Astrand and Rodahl (8) that physical training may effect an increase in the depth of respiration and a corresponding dimunition of RR. The result of this study lends credence to the same principle, inasmuch as the pulmonary ventilation per minute was reasonably constant. The obvious external sign of such a training effect is breathing in a relaxed state. All the same, the decrease

of RR in the Yoga group is a finding which cannot be equated with the observation of Astrand and Rodahl because the type of physical training involved varied widely. Static exercise as in *Asanas* do not create the same functional reactions in the body as dynamic exercises.

The differences noticed between Yoga and 5BX groups may be attributed to the emphasis on breathing in Yoga training. The depth of respiration created in Yoga exercises must be due not so much to the exercise as the use of *Pranayama* methods involving deep but consciously controlled rhythm in breathing. While the post-training difference in RR (T1 = 10.1; T2 = 10.5) is small, the difference in TV (T1 = 477; T2 = 455) is greater. A comparison between minute ventilation and related O_2 consumption does not seem to signify any importance in this regard, as the Yoga group had higher BMR due to a larger consumption of O_2.

4. Respiratory Quotient

The RQ of the subjects used in this study was in the close vicinity of 0.82, indicating a post-absorptive state. Besides being a check on the basal state, the result of this measurement came in handy to apply a standard conversion of the amount of O_2 consumed into Kcal. At a nonprotein RQ of 0.82, the caloric value of a liter of O_2 is 4.825. The calculation based on an assumed RQ of 0.82, as done in this study, was thus, an acceptable approach for the calculation of BMR (68).

Training does not seem to have any significant effect on RQ.

HEMOGLOBIN, HEMATOCRIT AND RED CELL COUNT

Following the training program, hemoglobin, hematocrit and red blood cell count of the Yoga group showed significant increases. The gain in each of these three parameters being fairly uniform, there was no appreciable change in indices, and in the normal qualities of the red cell. The higher value of hematocrit was not caused by macrocytic tendency, but it was due to an increase in the number of red cells. By the same token, the normochromic condition had been maintained. A higher concentration of hemoglobin taken together with a rise in cell number, is a factor useful in O_2 delivery to the tissues and in the exchange of metabolities.

Yogendra (122) reasoned that *Pranayama* enables the red blood cells to live their full life. If the normal disintegration does not occur and production does not correspondingly diminish, the cell count is bound to increase. Yogendra's claim is questionable because blood formation depends upon food factors including the intrinsic factor, folic acid and B_{12} vitamin; it cannot be concluded that *Pranayama* helps to sustain lives of the cells unless replacements are also studied and definite methods are devised to trace the lives of individual cells. Mere cell count is but one of the many factors involved.

However, the activities of the red blood cells are closely linked up with the question of the effects of Yoga practice on bodily functions, since claims are often made that Yogis in *Samadhi* or Intense Concentration need only little air and food. There is some truth in the claims, but a study of this subject is likely to be fraught with many complications difficult of solution, as erythrocyte

formation in the bone marrow and the spleen's part in maintaining the cell levels have to be necessarily linked up with the nutritional conditions during training.

PHYSICAL WORK CAPACITY AND MAXIMAL OXYGEN CONSUMPTION

The higher intensity of exercise was largely responsible for the significant improvement of the 5BX group in PWC_{170} and maximal O_2 consumption. In general, physical training seems to have a wide range of effects on maximal O_2 consumption (5 to 43% improvement; different subjects under different conditions) as given by Massicotte (80). The improvement observed in this study was 11.4% above the initial level. The factors which induced such a change were not investigated. A larger cardiac output and an increase in arteriovenous O_2 differences as given by Ekblom (45) would offer a possible explanation. Yoga training did not have sufficient impact on the O_2 transport system to elicit a training effect on PWC_{170} or maximal O_2 consumption.

The post-training PWC_{130} scores indicated that both 5BX and Yoga groups had improved significantly. A result of this nature should be expected of the 5BX group subjects because of their general improvement in PWC_{170}. Yoga group's improvement cannot be attributed to a similar cause, as their PWC_{170} did not change. Nevertheless, the indications are that the Yoga subjects developed efficiency at a moderately high (130 per min.) HR. While further investigations are needed to evaluate this phenomenon fully, the decrease in resting pulse, and increase in hemoglobin and red cell count may be given as probable causes. But, a consideration of what caused PWC_{130} values

to drop after detraining, while hemoglobin, red cell count and HR did not change, requires further investigation into the factors associated with physical performance levels. The fact that detraining caused a decline in flexibility is perhaps an indication that mechanical efficiency was affected owing to changes in the joints and the surrounding tissues.

VITAL CAPACITY, BREATH-HOLDING AND CHEST EXPANSION

The Yoga and 5BX groups significantly improved in vital capacity, breath-holding time and chest expansion after training. The improvement shown by the Yoga group in the three parameters was greater, which was probably due to the effect of breathing exercises involving hyperventilation and breath-holding.

While some researchers seem to indicate that physical training has no effect on vital capacity; based on the findings of others, Astrand and Rodahl (8) concluded that it is likely to increase in the case of young people. It is necessary to note that in young people the effects of natural growth may be a confounding factor. As regards Yoga, there is positive evidence that *Asanas* coupled with *Pranayama* will cause an increase in vital capacity (21, 112).

From a physiological point of view, vital capacity, breath-holding and chest expansion measurements do not seem to be important. Nevertheless, the implication of these external manifestations can only be determined by further scientific probe into their consequences.

FLEXIBILITY

The results of the tests on flexibility pointed out that due to training, the Yoga and 5BX groups had improved significantly. The difference between the two groups was also significant. This finding is in disagreement with that of DeVries (38) who found no difference between the effects of *Asana*-type exercises and fast-stretching calisthenics.

The nature of movements involved in *Asanas* is such that it acts directly on the joints, especially the ligaments, cartilages and tendons to make them more mobile. Further, because of the special emphasis placed on the flexibility of the spine in Yoga training, it seems natural to expect better results in tests like the Wells Sit and Reach (118).

HEART RATE

1. Maximal HR

The pre-training and post-training maximal HR of the Yoga group were not significantly different. It is generally understood that maximal HR is not affected by short-term physical training (45, 67).

2. HR. Response to *Sarvangasana*

The HR registered a moderate rise while the *Asana* was being performed. This would indicate that the physical work involved in that exercise is mild; and as claimed in some Yoga literature (55) it places no strain on the cardiac or other organic functions.

The inverted body position in *Sarvangasana* would seem to offer many advantages ensuring pleasurable exercise. Gravitational effects on circulation seem to involve not only multiple changes of a mild nature in regulating cardiac action, but also in the hormonal functions, as in the thyroid and even on the nerve centers of the brain. Such a regulation of physiological functions have apparently a soothing effect on the body as a whole and an inverted position would seem to minimize functional activities in the elevated sections of the body. These are, however, special issues which require elaborate and complex methods of investigation which were beyond the scope of this study. In this study, the time factor (the duration of the *Asana*) was limited, but long practice may involve much more permanent changes than are noticeable in research studies of the present type.

PULSE DECELERATION

1. Relaxation

It was found that *Savasana* is a more effective way of relaxing (observation limited to decelerating pulse) than merely lying down on the back. Although both are essentially supine, *Savasana* is a definite technique in which a conscious effort is involved as relaxation. The reduced cardiac activity presumably results from a more economical organization of bodily functions. Govindarajulu (54) and Kuvalayananda (71) have outlined the efficacy of this *Asana* as a scientific way of relieving fatigue and attaining a type of rest that is refreshing.

Savasana has been used to fight morbidity that accompanies hypertension. Datey et al. (34) who treated hypertensive patients

with *Savasana* found that many of them responded favorably and had their blood pressure reduced. It would appear that *Savasana* influences the circulatory system via nervous channels and tones down its activities.

2. After Exercise

Restitution of HR after exercise occurs more rapidly in trained people than in the untrained. Even a trained person has to follow a certain post-exercise procedure in order to facilitate pulse deceleration. Of the three methods compared, *Savasana* proved to be the most effective. This suggests that *Savasana* could have a wider application in sports training, but the scope is limited to some extent as one has to have Yoga experience before trying it.

There is not sufficient data in this experiment to ascertain the effectiveness of *Savasana* in venous return which is considered an important physiological factor in exercise. The faster recovery is perhaps induced by a general state of relaxation attained in *Savasana*.

This experiment also suggests that a process of tapering off with mild exercise, is a more effective way of recovering than resting in a sitting position.

DETRAINING

It is generally understood that certain training effects may be merely transitory and others may last for a considerable period of time, resulting in adaptations. In this study, after detraining, the Yoga group showed a significant decline in flexibility, breath-holding and PWC_{130}. The other measurements, including BMR, did not indicate any significant changes.

Discontinuation of training seems to curtail the mobility of the joints and hence, flexibility declines. Lack of regular practice of *Pranayama* is likely to alter tolerance of suspended respiration. What causes the PWC_{130} rating to drop is not exactly known. It may be surmised that the period of training in this study was not long enough and continued to ensure the maintenance of the effects. Traditionally, Yoga is a way of life and so, detraining has no place in its system.

METABOLIC COST OF TM AND *SAVASANA*

The metabolic rate, as determined by O_2 consumption, dropped significantly during *Savasana* and TM. Though the two techniques are different, there are common characteristics, and perhaps they have certain similar physiological responses. It was not within the scope of this study to ascertain the exact nature of such responses.

The practices involve a natural and gradual, but slow effort to obtain profound rest and lessen the response to sensory distractions around. These practices lead to a state of complete relaxation, wherein tension and stress are relieved. The physiological changes that follow provide enjoyable and refreshing experiences to the subjects. The hypometabolic state so induced is an indication that the body is maintaining its normal physiological functions with a subnormal amount of O_2.

The reduced O_2 consumption does not seem to cause any ill effects; on the other hand, the subject experiences euphoria. The physiological implication is far deeper than the mere O_2 consumption.

As suggested by Orme-Johnson (90) the practice of TM may be influencing autonomic balance by increasing parasympathetic and decreasing sympathetic activity. Such a change in nervous function is likely to bring about changes other than O_2 consumption. Wallace et al. (117) found that during TM practice, skin resistance increased and blood lactate level decreased, while the alpha rhythm of the brain wave pattern became prominent. Partial pressure of CO_2 and O_2 did not show any appreciable change. In another study, Wallace (114) observed a 20% drop in O_2 consumption in TM subjects after meditation.

While practicing *Savasana*, the subject remains inwardly alert but is less conscious of the external environment. *Savasana*, involving as it does, a willed withdrawal of stimuli from all sections of the body, results in considerable muscular relaxation, leading to a sort of hypnotic state of inactivity, but under the influence of a concentrated thought of pretended death. Datey et al. (34) postulated that this Yoga exercise probably influences the hypothalamus through the continuous feed-back of slow, rhythmic proprioceptive and enteroceptive impulses and tends to set it at a lower pace, thereby reducing metabolic activities.

In this study, the drop in O_2 consumption during TM (15.5%) was more significant than what was observed in *Savasana* (10.3%) in spite of the fact the former is done in a sitting position and the latter in supine posture. This is to be regarded as the difference in the effectiveness of the two methods. The mental pronunciation of sounds in TM perhaps influences the nervous system more effectively than the mere breathing-based relaxation of *Savasana*, wherein

the will is consciously used to obtain relaxation. As regards the Control subjects, the drop in their O_2 consumption (3.5%) was due to the natural effect of postural change, from sitting to a supine position.

The subjects of the TM group did not have indentical experience in meditation at the time of testing. Nevertheless, no correlation was observed between their experience and performance. It would appear that the systematic training available for the students of TM is adequate to enable them to derive the benefits of meditation within a short period. This observation is in conformity with the remark contained in the report of Wallace (114).

The complexity of the techniques of TM and *Savasana* and the time factor merit consideration. While TM is simple and learned quickly, it takes a much longer time to become proficient in *Savasana*. The usual time limit for a single practice in TM is 15 to 20 minutes. No time is specified for *Savasana*, and some Yoga Practitioners may do it for 30 minutes or more. In this study, the subjects were tested on a fifteen-minute practice. It is not possible to predict, from the available data, the consequence of the practice for an extended period of time.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

SUMMARY

The physiological effects of *Hatha* Yoga, 5BX Plan and Transcendental Meditation were investigated, using 51 male students aged 17 to 22 years as subjects. In the first part of the study, the pre-training tests were administered on 44 subjects, and subsequently, they were randomly assigned to three treatments, T1 (Yoga), T2 (5BX) and T4 (Control). T1 group received *Hatha* Yoga training for six weeks and T2 group was trained as per the 5BX Plan for six weeks. T4 group received no training and they were asked to maintain the same physical activity level to which they were used. All the subjects were tested after the six-week period. The data collected were subjected to statistical tests of significance. The BMR of T1 group increased (from -0.26% to 5.33%) while that of T2 and T4 groups did not show any significant change. While T2 group improved in maximal O_2 consumption (from 3.26 to 3.71 lit/min.) no significant changes were observed in the other two groups.

In the second part of the study, tests were made after training was discontinued for six weeks and the subjects of T1 group were asked to maintain their normal life style, without practicing Yoga. The post-detraining results were compared with the post-training results and the differences were statistically tested for significance. Significant deterioration was observed in flexibility as determined

by Wells Sit and Reach Test (from 11.3 to 6.0 cm.), breath-holding (from 66.1 to 57.4 sec.) and PWC_{130} (from 640 to 564 kpm/min.).

In the third part of the study, seven volunteer subjects of T1 group were trained in *Hatha* Yoga for a further period of six weeks. Following this retraining period, their metabolic rate while practicing *Savasana* was determined. Seven volunteers (T3 group) who had experience in Transcendental Meditation were tested the same way while they practiced meditation. The metabolic cost of resting in supine position was calculated, using seven volunteer subjects of T4 group. The statistical analysis of the results revealed the following drop (compared to a pre-treatment estimate) in O_2 consumption: T1 = 10.3%, T3 = 15.5% and T4 = 3.5%. The difference within and between groups were significant.

CONCLUSIONS

It is concluded that, within the limitations of this study, Yoga training and detraining, 5BX training, *Savasana* and TM have the following physiological effects on young adults.

YOGA

1. BMR and T-4 thyroxine increase within a certain range, without upsetting the state of euthyrodism, indicating heightened activity of the thyroid gland.

2. Certain changes occur in the cardiovascular and oxygen-transport systems, resulting in slower HR and RR in the basal state, higher O_2 consumption in the basal state, and moderate increase in hemoglobin, hematocrit and RBC Count.

3. Flexibility improves with training, and detraining causes a sharp decline. Detraining also affects cardiovascular efficiency, as seen by decreased performance in PWC_{130}.

5BX

4. Aerobic capacity in general, and specifically PWC and maximal O_2 consumption improve appreciably.

SAVASANA

5. The rest and relaxation obtained in *Savasana* facilitate faster pulse deceleration following exercise.

6. During the practice of *Savasana*, the level of O_2 consumption drops markedly, indicating a state of profound rest. This hypometabolic state is marked by no disturbance in the homeostasis of RQ.

TRANSCENDENTAL MEDITATION

7. The metabolic rate during TM decreases to a level normally seen in sound sleep, while the RQ remains constant.

To sum up the conclusions of this study and to relate the conclusions to the practical aspects of physical education, the following observations are made.

1. A life style eliminating physical training does not produce the physiological changes necessary to develop fitness.

2. The 5BX Plan is an effective way of developing aerobic capacity and fitness.

3. Transcendental Meditation is efficacious in providing physiological and mental rest and as such, it has scope for application in fitness and athletic training.

4. *Hatha* Yoga is an excellent health builder. It does not seem to promote cardiovascular fitness; but for some unknown reason, it enhances the general efficiency of the heart, lungs and the oxygen-transport system.

Hatha Yoga also seems to influence the endocrine glands and the humoral system, and generally strengthen the vital functions of the body. Further, it assures a feeling of euphoria and develops poise and self-confidence.

The scope for the application of Yoga in sports and athletic training seems great. It is likely that Yoga will complement the outcomes of sports training. Nevertheless, caution should be exercised, inasmuch as the basic principles of Yoga will have to be maintained in implementing such an idea. Indiscriminate mixing of two systems may cause unhealthy effects.

Finally, the lessons of Yoga tradition, especially the controls to safeguard health deserve consideration for inclusion in modern physical education, for they facilitate physiological progress and offer immense psychological benefits of a kind specially valuable in the present stressful conditions of life.

RECOMMENDATIONS

Scientific investigation of the physiological effects of Yoga is in an infant stage. To further the knowledge in this regard, a few recommendations are offered here:

1. Longitudinal studies, in which the progress of the same subjects is followed for a longer period, to determine the long-term effects.

2. Controlled experiments to study the value of Yoga introduced and taught as given in traditional literature.

3. Research to assess the application of Yoga to sports in matters related to flexibility and other factors which may contribute to athletic skill and work capacity.

4. Studies to determine the effects of training that combines a physical fitness program like the 5BX Plan and Yoga, or sports participation and Yoga.

5. Experiments to determine the influence of Yoga on people of different age groups, both sexes, and classified homogenous groups based on initial abilities.

6. Diet controlled research to study the physiological effects of Yoga.

REFERENCES

1. Alexander, J., M. Howell, R. Fraser and B. Sproule, "An Evaluation of the 5BX Program of Exercises by Certain Physiologic Responses to a Treadmill Test," Unpublished paper, University of Alberta, 1962.

2. Allison, J., "Respiratory Changes during Transcendental Meditation," The Lancet, 1:833-834, 1970.

3. Amersham-Searle, "Thyopac-4 Kit for Assay of Total Thyroxine - Description, Principle and Application," Unpublished pamphlet, G.D. Searle & Co. and the Radiochemical Centre, 1972.

4. Anand, B.K. and G.S. Chhina, "Investigations on Yogis Claiming to Stop their Heart Beats," Indian Journal of Medical Research, 49: 90-94, 1961.

5. Andersen, K.L., "Performance and Recovery Pulse Rate Studies in the Norwegian Army," Military Medicine, 116:32-36, 1955.

6. Aranya, S.H., Yoga Philosophy of Pantanjali, translated by P.N. Mukerji, Calcutta: University of Calcutta, 1963.

7. Astrand, P.O., "Human Physical Fitness with Special Reference to Sex and Age," Physiological Reviews, 36:307-335, 1956.

8. Astrand, P.O. and K. Rodahl, Textbook of Work Physiology, New York: McGraw-Hill Book Company, 1970.

9. Astrand, P.O. and I. Ryhming, "A Nomogram for Calculation of Aerobic Capacity (Physical Fitness) from Pulse Ratio during Sub-maximal Work," Journal of Applied Physiology, 7:218-221, 1954.

10. Aurobindo, S., Dictionary of Aurobindo's Yoga, compiled by M.P. Pandit, Pondicherry: Dipti Publications, 1966.

11. Baisset, A., R. Bastouil and P. Germain, "Modification of Basal Metabolism under the Influence of Physical Training," Revue Canadienne de Biologie, 4:461-476, 1945, Cited in Bender, J.A.

12. Banister, E.W. and S.R. Brown, "The Relative Energy Requirements of Physical Activity," in Exercise Physiology edited by H.B. Falls, New York: Academic Press, 1968, pp. 267-322.

13. Banister, E.W., S.R. Brown, H.R. Loewen and H.C. Nordan, "The Royal Canadian Air Force 5BX Program - A Metabolic Evaluation," Medical Services Journal, Canada, 23:1237-1244, 1967.

14. Bates, R.A., "Flexibility Training: the Optimal Time Period to Spend in a Position of Maximal Stretch," Unpublished Masters thesis, University of Alberta, 1971.

15. Becker, D.V., "Metabolic Indices," in The Thyroid, edited by S.C. Werner and S.H. Ingbar, New York: Harper and Row, 1971, pp. 269-280.

16. Bender, J.A., "Effects of Exercise on Basal Metabolism," Unpublished Doctoral dissertation, University of Illinois, 1951.

17. Bernard, T., Hindu Philosophy, New York: Philosophical Library, 1947.

18. Bhattacharya, P.K., Unpublished personal communication, July 1972.

19. Bhole, M.V. and P.V. Karambelkar, "Heart Control and Yoga Practices," Yoga-Mimamsa, 13(4):53-65, 1971.

20. Bhole, M.V. and P.V. Karambelkar, "Effects of Yogic Treatment on Blood Picture in Asthma Patients," Yoga-Mimamsa, 14(1 & 2):1-6, 1971.

21. Bhole, M.V. and P.V. Karambelkar, "Effect of Yoga Training on Vital Capacity and Breath-holding Time," Yoga-Mimamsa, 14(3 & 4): 19-26, 1971 and 1972.

22. Bhole, M.V., P.V. Karambelkar, and S.L. Vinekar, "Underground Burial or Bhugarbha Samadhi," Yoga-Mimamsa, 10(2):2-16, 1967.

23. Boothby, W.M. and I. Sandiford, Laboratory Manual of the Technic of Basal Metabolic Rate Determinations, Philadelphia: W.B. Saunders Company, 1920.

24. Brouha, L., Physiology in Industry, Oxford: Pergamon Press, 1960.

25. Brown, A.C. and G. Brengelmann, "Energy Metabolism" in Physiology and Biophysics, edited by T.C. Ruch and H.D. Patton, Philadelphia: W.B. Saunders Company, 1965, pp. 1030-1049.

26. Buxton, D., "Extension of the Kraus-Weber Test," Research Quarterly of AAHPER, 28:210-217, 1957.

27. Cartwright, G.E., Diagnostic Laboratory Hematology, New York: Grune and Stratton, 1968.

28. Catt, K.J., "ABC of Endocrinology," The Lancet, 1:1383-1389, June, 1970.

29. Chidananda, S., Yoga-Vendanta Forest Academy Lectures, Rishikesh: Yoga-vendanta Forest Academy, 1960.

30. Consolazio, F.C., R.E. Johnson and L.J. Pecora, Physiological Measurements of Metabolic Activity in Man," New York: McGraw-Hill, 1963.

31. Cooper, L.A., "A Comparison of the Effects of Short Intensive and Prolonged Intensive Exercise Program on Treadmill Performance and Certain Cardio-Respiratory Functions," Unpublished paper presented to the First Canadian Fitness Seminar, Saskatoon, 1963.

32. Cureton, T.K., "Health and Fitness in the Modern World and What Research Reveals," Journal of Physical Education, 70:239-243 and 264, 1972.

33. Cureton, T.K. and E.E. Phillips, "Physical Fitness Changes in Middle Aged Men Attributable to Eight-Week Periods of Training, Non-training, and Retraining," Journal of Sports Medicine and Physical Fitness, 4:87-93, 1964.

34. Datey, K.K., S.N. Deshmukh, C.P. Dalvi and S.L. Vinekar, "Shavasan: a Yogic Exercise in the Management of Hypertension," Angiology, 20:325-333, 1969.

35. Davis, J.E. and N. Brewer, "Effects of Physical Training on Blood Volume, Hemoglobin, Alkali Reserve and Osmotic Resistance of Erythrocytes," American Journal of Physiology, 113:586-591, 1935.

36. Day, H., The Study and Practice of Yoga, New York: University Books, 1955.

37. Devi, I., Renew your Life through Yoga, London: George Allen and Unwin Ltd., 1965.

38. De Vries, H.A., Physiology of Exercise, Dubuque: Wm. C. Brown Company Publishers, 1970.

39. Dhanaraj, V.H. (Ed.), Y.M.C.A. Physical Fitness Scheme, Madras: Department of Literature - National Council of YMCAs of India, 1965.

40. Dhanaraj, V.H. "Effects of Selected Asanas on Heart Rate," Unpublished report of a pilot project preparatory to a Doctoral dissertation, University of Alberta, 1972.

41. Digambarji, S. and Staff of Research Departments in Kaivalyadhama, "Place of Yoga in Welfare Work," Yoga-Mimamsa, 12(2):19-38, 1969.

42. Dill, D.B., "The Economy of Muscular Exercise," Physiological Reviews, 16:263-291, 1936.

43. DuBois, E.F., Basal Metabolism in Health and Disease, Philadelphia: Lea and Febiger, 1936.

44. DuBois, D and E.F. DuBois, "A Formula to Estimate the Approximate Surface Area if Height and Weight be Known," Archives of Internal Medicine, 17:863-871, 1916.

45. Ekblom, B., "Effect of Physical Training on Oxygen Transport System in Man," Acta Physiologica Scandinavica, Supplement 328:9-40, 1969.

46. Elbel, E.R. and R.M. Holmer, "The Relationship between Pre-Exercise Pulse Rate and Recovery following Exercise," Research Quarterly of AAHPER, 20:367-377, 1949.

47. Fardy, P.S., "Effects of Soccer Training and Detraining upon Selected Cardiac and Metabolic Measures," Research Quarterly of AAHPER, 40:502-508, 1969.

48. Faulkner, J.A., G.J. Brewer and J.W. Eaton, "Adaptation of the Red Blood Cell to Muscular Exercise," Advance in Experimental Medicine and Biology, 6:213-227, 1969.

49. Gemmill, C.L. and J.R. Brobeck, "Energy Exchange," in Medical Physiology, edited by V.B. Mountcastle, Saint Louis: The C.V. Mosby Company, 1968, pp. 473-497.

50. Gharote, M.L., "Group Technique of Introducing Yogic Practices," Yoga-Mimamsa, 13(4):41-44, 1971.

51. Gharote, M.L., "Energy Expenditure During Deep Meditative State," Yoga-Mimamsa, 14(1 & 2):57-62, 1971.

52. Gharote, M.L., "A Psychophysiological Study of the Effects of Short-term Yogic Training on the Adolescent High School Boys," Yoga-Mimamsa, 14(1 & 2):92-99, 1971.

53. Govindarajulu, L.K., Unpublished presidential address on national fitness, All-India Educational Conference, Bombay, 1938.

54. Govindarajulu, L.K., "Yogic Asanas and their Place in Modern Physical Education," Vyayam, 19(3):1-5, 1948; 19(4):1-8, 1948; 20(1): 1-6, 1948; 20(2): 1-6, 1949.

55. Govindarajulu, L.K., Unpublished personal communication, June 1972.

56. Guyton, A.C., Textbook of Medical Physiology, Philadelphia: W.B. Saunders Company, 1969.

57. Herxheimer, H., "Heart Rate in Recovery from Severe Exercise," Journal of Applied Physiology, 1:279-284, 1948.

58. Hoeing, J., "Medical Research on Yoga," Confinia Psychiatrica, 11:69-89, 1968.

59. Hoffman, W.S., The Biochemistry of Clinical Medicine, Chicago: Year Book Medical Publishers, Inc., 1970.

60. Honeywell, "Electronic Medical System," Unpublished operation and maintenance manual (3-52284), Honeywell Inc., Test Instruments Division, Denver.

61. Horrobin, D.F., Medical Physiology and Biochemistry, London: Edward Arnold (Publishers) Ltd., 1968.

62. Howell, M.L. and R.B.J. Macnab, The Physical Work Capacity of Canadian Children aged 7 to 17, Toronto: The Canadian Association for Health, Physical Education and Recreation, 1968.

63. Ingbar, S.H., "Tests of Hormones in Blood: Clinical Considerations," in Thyroiod, edited by S.C. Werner and S.H. Ingbar, New York: Harper & Row, 1971, pp. 243-255.

64. Joshi, K.S., Yoga and Personality, Allahabad: Udayana Publications, 1967.

65. Keating, F.R., "In Defence of the Basal Metabolic Rate," Journal of Clinical Enocrinology and Metabolism, 17:797-800, 1957.

66. Kendrick, Z.V., M.L. Pollock, T.N. Hickman and H.S. Miller, "Effects of Training and Detraining on Cardiovascular Efficiency," American Corrective Therapy Journal, 25:79-83, 1971.

67. Kenhr, C.A., D.B. Dill and W. Neufeld, "Training and its Effects on Man at Rest and at Work," American Journal of Physiology, 138: 148-156, 1942.

68. Knoebel, L.K., "Energy Metabolism," in Physiology, edited by E.E. Selkurt. Boston: Little, Brown and Company, 1971, pp. 603-618.

69. Krishna, G., The Secret of Yoga, New York: Harper and Row, Publishers, 1972.

70. Kuvalayananda, S., "The Rationale of Yogic Poses," Yoga-Mimansa, 2(3):207-217, 1926.

71. Kuvalayananda, S., "Savasana," Yoga-Mimansa, 2(3):229-232, 1926.

72. Kuvalayananda, S., "The Rationale of Yogic Poses," Yoga-Mimansa, 3(1):45-52, 1928.

73. Kuvalayananda, S., "Viparita Karani or The Inverted Action," Yoga-Mimansa, 3(1):57-59, 1928.

74. Kuvalayananda, S., "Freedom from Emotions - A Physiological Necessity of Yogic Life," Yoga-Mimansa, 3(2):146-150, 1928.

75. Kuvalayanda, S., "Jalandharabandha," Yoga-Mimamsa, 6(4):301-304, 1957.

76. Kuvalayananda, S., "Yoga-Notes," Yoga-Mimamsa, 7(4):42-78, 1958.

77. Landry, F., "Illustration du cout energetique du programme d'en trainement 5BX," Mouvement, 1:247-258, 1966.

78. Macnab, R.B.J., P.R. Conger and P.S. Taylor, "Differences in Maximal and Submaximal Work Capacity in Men and Women," Journal of Applied Physiology, 27:644-648, 1969.

79. Majumdar, S.K., Introduction to Yoga Principles and Practices, New York: University Books, 1966.

80. Massicotte, D.R., "Cardiorespiratory Adaptations to Training at Specified Intensities in Children," Unpublished Doctoral dissertation, University of Alberta, 1972.

81. Mathews, D.K., Measurement in Physical Education, Philadelphia: W.B. Saunders Company, 1963.

82. McCue, B.F., "Flexibility Measurements of College Women," Research Quarterly of AAHPER, 24:316-324, 1953.

83. Miale, J.B., Laboratory Medicine - Hematology, St. Louis: C.V. Mosby Co., 1967.

84. Michael, E., J. Evert and K. Jeffers, "Physiological Changes of Teen-age Girls during Five Months of Detraining," Medicine and Science in Sports, 4:214-218, 1972.

85. Miles, W.R., "Oxygen Consumption during Three Yoga-type Breathing Patterns," Journal of Applied Physiology, 19:75-82, 1964.

86. Miller, A.T. and C.S. Blyth, "Lean Body Mass as a Metabolic Reference Standard," Journal of Applied Physiology, 5:311-316, 1953.

87. Montoye, H.J., "Inter-relation of Maximum Pulse Rate during Moderate Exercise, Recovery Pulse Rate and Post-exercise Blood Lactate," Research Quarterly of AAHPER, 24:453-458, 1953.

88. Nayer, D., M. Ostyn and D. Visscher, "Effect of Training on the Serum Free Thyroxine in Athletes," Annales D'Endocrinologie, 31: 721-723, 1970.

89. Orban, W.A.R., Unpublished communication addressed to the Prime Minister of Canada, October, 1962.

90. Orme-Johnson, D.W., "Autonomic Stability and Transcendental Meditation," Proceedings of the First International Symposium on the Science of Creative Intelligence, California, 1971.

91. Passmore, R., "Basal Energy Metabolism at Various Ages," in Metabolism, edited by P.L. Altman and D.S. Dittmer, Bethesda: Federation of American Socieites for Experimental Biology, 1968, p. 345.

92. Patanjali, The Yoga-System of Patanjali, rendered by J.H. Wood, Harvard Oriental Series, Delhi, 1966.

93. Radhakrishnan, S., Indian Philosophy - Vol. II, London: George Allen & Unwin Ltd., 1962.

94. Rangan, S.C.B., "An Experimental Study to Investigate the Effect of Sarvangasana and Halasana on the Basal Metabolic Rate," Unpublished Masters thesis, Jiwaji University, 1969.

95. Rao, S., "Metabolic Cost of Head-stand Posture," Journal of Applied Physiology, 17:117-118, 1962.

96. Rathbone, J.L., Corrective Physical Education, Philadelphia: W.B. Saunders Co., 1959.

97. Rele, V.G., Yogic Asanas for Health and Vigour, Bombay: D.B. Taraporevala Sons & Co. Pri. Ltd., 1960.

98. Rhodes, B.A., "Effect of Exercise on the Thyroid Gland," Nature, 216:917-918, 1967.

99. Robertson, J.D. and D.D. Reid, "Standards for the Basal Metabolism of Normal People in Britain," The Lancet, 262:940-943, May 1952.

100. Romanowski, W., H. Szwarc, S. Barowiec, K. Baranski, H. Seyfried and P. Wierzbicki, "Studies on Physiological and Psychological Evaluation of the Yoga System Exercises," Wychowanie Fizyczne I. Sport, 13(3):139-170, 1969.

101. Royal Canadian Air Force, 5BX Plan for Physical Fitness, Ottawa: Queen's Printer and Controller of Stationery, 1958.

102. Royal Canadian Air Force, 5BX Plan for Physical Fitness, Ottawa: Queen's Printer and Controller of Stationery, 1970.

103. Shephard, R.J., "Intensity, Duration and Frequency of Exercise as Determinants of the Response to a Training Regime," Internationale Zeitschrift fuer Angewandte Physiologie, 26:272-278, 1968.

104. Simri, U., N. Laufer and C. Rosenbluet, "A Comparison Between the Flexibility Tests of Correnti and of the International Committee for the Standardization of Physical Fitness Tests," Unpublished paper, Wingate Institue for Physical Education and Sports, 1972.

105. Sjostrand, T., "Changes in the Respiratory Organs of Workmen at an Ore Smelting Works," Acta Medica Scandinavica, 198:687-699, 1947.

106. Stallman, R.K., "The Metabolic Cost of the 5BX Plan for Physical Fitness," Unpublished Masters thesis, University of Illinois, 1963.

107. Steadward, B. and M. Singh, "Effects of Jogging on Heart Rate, Blood Pressure, Vital Capacity, Body Fat and Physical Work Capacity," Unpublished paper presented to A.C.S.M. Meeting, Albuquerqui, New Mexico, 1970.

108. Steinhaus, A.H., "Exercise and Basal Metabolism in Dogs," American Journal of Physiology, 83:658-677, 1928.

109. Steinhaus, A.H., "Chronic Effects of Exercise," Physiological Reviews, 13:103-147, 1933.

110. Steinhaus, A.H. and J.E. Norris, Teaching Neuromuscular Relaxation - Comparative Research Project, Washington: U.S. Department of Health, Education and Welfare, 1964.

111. Tipton, C.M., R.J. Barnard and G.D. Tharp, "Cholinesterase Activity in Trained and Untrained Rats, Internationale Zeitschrift fur Angewandte Physiologie, 23:34-41, 1966.

112. Udupa, K.N., R.H. Singh and R.M. Settiwar, "Studies on Physiological, Endocrine and Metabolic Response to the Practice of Yoga in Young Normal Volunteers," Journal of Research in Indian Medicine, 6(3): 345-353, 1971.

113. Vinekar, S.L., "Yoga and the Rehabilitation of the Physically Disabled," Yoga-Mimamsa, 7(3):171-192, 1957.

114. Wallace, R.K., "Physiological Effects of Transcendental Meditation," Science, 167:1751-1754, 1970.

115. Wallace, R.K., "Scientific Research on Transcendental Meditation," Ottawa: Maharishi International Academy, 1972.

116. Wallace, R.K. and H. Benson, "The Physiology of Meditation," Scientific American, 226:85-90, 1972.

117. Wallace, R.K., H. Benson, and A.F. Wilson, "A Wakeful Hypometabolic Physiologic State," American Journal of Physiology, 221:795-799, 1971.

118. Wells, K.F. and E.K. Dillon, "Sit and Reach - a Test of Back and Leg Flexibility," Research Quarterly of AAHPER, 23:115-118, 1952.

119. Wenger, M.A., B.K. Bagchi and B.K. Anand, "Experiments in India on Voluntary Control of the Heart and Pulse," Circulation, 24:1319-1325, 1961.

120. Winer, B.J., Statistical Principles in Experimental Design, New York: McGraw-Hill Book Company, 1971.

121. Wood, E., Yoga, London: Cassell and Company Ltd., 1962.

122. Yogendra, S., Hatha Yoga Simplified, Bombay: The Yoga Institute, 1958.

123. Yogi, M.M., The Science of Being and Art of Living, London: International SRM Publications, 1966.

124. Yoshimura, H., "Anemia during Physical Training," Nutrition Reviews, 28:251-253, 1970.

APPENDIX A

QUESTIONNAIRES

PRE-TRAINING QUESTIONNAIRE

Name: .... Date of Birth: ....

Residence: .... Room No.: ..... Phone: ....

How much time do you spend on games, sports, physical recreation, etc.?

Hours/day ....; Days/week ....; weeks/year ....

Did you take part in any organized physical training during the last six months?

No.: ..... Yes: ..... Specify ....

Have you had experience in the following?

	No	Yes	Indicate No. of Months	Remarks
Yoga:	....	....	....	....
5BX:	....	....	....	....
TM:	....	....	....	....

Give particulars of chronic medical complaints, if any:

Past: ....

Present: ....

Medications: During the last 4 weeks ....

Present: ....

Smoking: No: ...... Yes: ...... Specify kind and number each day ......

....

What time do you normally (1) eat supper .... (2) go to bed ....

and (3) rise in the morning ....

Is the procedure of the experiment, described at the orientation, clear to you?

Yes: ..... No: ..... Would like more information ....

Other comments you wish to add ....

....

Date .... Signature ....

POST-TRAINING QUESTIONNAIRE

Name: .... Training: Yoga ..... 5BX .....

Circle one appropriate number of each question. Use the line below for additional information.

1 = Yes 2 = Partly True 3 = Not Sure 4 = No

During Training

1. Participation experience was satisfactory: 1 2 3 4

 ....

2. The sessions were physically taxing: 1 2 3 4

 ....

3. Maintaining the tempo of training was hard: 1 2 3 4

 ....

4. I understood fully the purpose of experiment: 1 2 3 4

 ....

5. My interest remained unabated: 1 2 3 4

 ....

After Training

6. My general health has improved: 1 2 3 4

 ....

7. I am now able to withstand more strain: 1 2 3 4

 ....

8. I now feel more light and relaxed: 1 2 3 4

 ....

9. Rest is now more refreshing and meaningful: 1 2 3 4

 ....

10. My mental concentration has improved: 1 2 3 4

 ....

Other comments, if any: ....

....

APPENDIX B

INSTRUCTIONS TO SUBJECTS AND TEST ASSISTANTS

BMR TEST - INSTRUCTIONS TO SUBJECTS

To:

Name: .... Residence: .... Room No. .....

As explained to you earlier, BMR is a measurement of your bodily activity under certain minimal conditions. Your cooperation is most essential to make the test reliable. The test comprises the collection of a sample of expired gases, which will be done while resting in bed in your room on .... at ...... A.M. Please observe the following carefully in order to prepare yourself for the test.

1. On the day prior to the test (ie. on ....) avoid strenuous physical activities.
2. Eat your supper by 5:00 P.M. the previous evening and totally avoid foods (solids or fluids) thereafter until the test is done. You may drink water.
3. Go to bed by 10:00 P.M. and try to get a good night's restful sleep.
4. The undersigned will meet you in your room in the morning. Change into underwear or underwear and socks, if you are not already so dressed. Remain in bed and rest, totally relaxed.
5. Do not smoke after waking up in the morning until the test is done.
6. Feel at home and relax.

<u>Note</u>:

The test is very simple. It will be done exactly the same way as taught in the practice session.

Your student leader will talk to you about preparations for the test; and he may remind you of your responsibilities. Please extend your cooperation.

If, for some reason, you are unable to prepare yourself for the test, phone the undersigned before 10:00 P.M. the previous evening.

Signature .... Phone ....

BMR TEST - INSTRUCTIONS TO TEST ASSISTANTS

Check the instruments. Make sure that the air in the Balloon has been already extracted.

Enter the test scores in this sheet as you follow the instructions in the same sequence.

Make an informal approach and help the subject to feel at home. Disconnect the telephone. Check the subject's body weight (dress: underwear or underwear and socks).

Name of Subject .... Weight ....

Ask the subject to lie on bed and relax. Get the following particulars from the subject, encouraging him to give truthful answers:

Time of last meal: .... Subsequent food if any: ....

.... No. of hours slept: ....

Smoking during last one hour: Yes ..... No .....

Any medication during last 24 hours: ....

Other observations: ....

Note and record his oral temperature, keeping the thermometer in the mouth for two minutes. During the same period, check his pulse for one minute.

Heart Rate: ...... Temperature ......

Moisten the mouth-piece with wet sponge provided. Fix the mouth-piece and arrange the Balloon, taking care to see that no discomfort is caused thereby to the subject. Do not open the valve. Instruct him to breath normally and maintain the same rhythm and depth of breathing. Let the subject relax for three minutes (Please

do not talk with him while he relaxes) and then, check his heart rate. If the heart rate appears high, give more time to relax.

Heart Rate after rest: ......

Any special observation ....

Ask the subject to practice breathing through the mouth for a minute. Now, fix the nose clamp. Wait for a minute, so as to ascertain the subject has made the necessary adjustments. Advise the subject again to remain relaxed and breath normally, and to stay awake.

Remove the Lock (curved metal piece and tape). Open the valve and simultaneously start the stopwatch (just before inpiration begins) for a five-minute collection. During the same period, observe his chest movements for two minutes and note the rate of respiration.

Respiratory Rate ......

The Balloon is large enough to hold a five-minute sample. But, if it is getting too full earlier, close the valve and stop the stopwatch the same time. Now for the last time,note and record his heart rate.

Sample collected for ..... min. and ..... sec.; subject was awake: ... . Subject slept ....; Heart rate after the test ......

Please see that the valve of the Balloon is closed properly and the Lock firmly replaced. Separate the Balloon from the hose and handle it carefully.

Put back the telephone. Inform the subject the test is over.

Date .... Time .... Balloon No. ......

Sample collected by ....

Comments, if any ....

PWC TEST - INSTRUCTIONS TO TEST ASSISTANTS

Preparation

1. Contact the subject and remind him of the date, place and time of testing.
2. Advise the subject to avoid strenuous exercise on the day of testing (prior to the test).
3. Instruct the subject to wear athletic costume.
4. Arrange the bicycle, ECG, stopwatch, etc. and see that they are in good working order.

Administration of Test

1. Ask the subject to take off his shirt and shoes. Check his body weight.
2. Let the subject sit in a chair and relax for awhile.
3. While the subject is resting, discuss briefly with him the testing procedure (The procedure has been already explained at the orientation. The subject also had a chance to practice. So, a quick review only is required).
4. Adjust the height of the bicycle seat and let the subject sit on it. Attach the electrodes and make all the other necessary connections.
5. Check the resting heart rate. If it appears to be too high, allow some more resting time.
6. Start the test and keep time carefully.
7. Use your discretion to set the work loads to maintain progression and get a heart rate close to 170 towards the end of the third period.

8. Record all the necessary observations in the test form provided.

Follow-up

1. Make sure that the test form is filled in completely, including time of testing, bicycle number and calibration, if any.
2. Save the used ECG paper and write the subject's name on it.
3. Rearrange all the equipment.

Note: Subsequent tests for the same subject should be arranged at the same time of day.

APPENDIX C

BLOOD TESTS - METHODS

HEMOGLOBIN

The Fisher Hemophotometer is set to read 14 grams and then, it is connected to an electrical outlet. The instrument is calibrated with two known standards, one having a high value of 14 gm/100 ml. and the other a low value of 5 gm/100 ml. The tube containing the standard is placed in the sample receptacle and pressed down to activate the exciter lamp. The calibration knobs "Hi" and "Lo" are adjusted until the meter reads correctly the given value. The procedure is repeated to ascertain that the instrument has been accurately calibrated.

Drabkin's solution is used as the reagent. To a tube containing 5 ml. of the reagent, 0.02 ml. of blood, already treated with an anticoagulant, is added. (Drabkin's solution is handled carefully as it contains cyancide, a poisonous substance). After mixing, it is poured into a photometer tube and the mixture is allowed to stand for five minutes. Then it is placed in the sample receptacle of the Hemophotometer, and a direct reading is obtained.

The hemoglobin value is expressed in grams per hundred milliliters of blood. The normal range in adult males is given as 13 to 17 gm/100 ml.

HEMATOCRIT

The Micro Method is used to determine the packed cell volume. The capillary tubes are filled to two-thirds with blood, already treated with an anticoagulant. The colored end of each tube is then sealed.

The tubes are placed in the hematocrit tray with sealed ends towards the outside and centrifuged at 12,000 rpm for five minutes.

The Micro Capillary Reader is used to determine the packed cell volume. The value represents the volume of RBC in a sample of whole blood expressed as a percentage. The normal range in males is given as 40 to 54%.

RED CELL COUNT

Coulter Counter B is an instrument used to count the number of red blood cells in a given sample. By a careful process of mixing, a (sample blood, already treated with an anticoagulant) 1 in 50,000 (coulter diluent) solution is obtained. To eliminate pipetting error, the solution is prepared in duplicate.

The solution is poured into a specimen beaker. The settings of the counter are kept at: Threshold 10, Aperture 16 and Attenuation 707, as given in the Manual. After the reading is made, the Threshold is changed to 8 and a second reading is taken. The values are read to the nearest 100 and corrected as per the coincidence chart. The corrected value is then multiplied by 100 to express the total red cell count per cubic millimeter of blood.

Corrected duplicate values on the same Threshold should agree to 100,000 rounded off. Counts on Threshold 10 and 8 on the same sample should agree within 200,000. If it is not so the count is made on a different Threshold until a stable value is obtained. The average count is taken as the result.

The duplicate tubes should agree to difference of 200,000 or less. If not, the test is repeated with another specimen of the same blood sample.

The RBC count is generally expressed in millions per cubic millimeter of blood. The normal range in males is given as 4.6 to 6.2 mil/c.mm.

T-4 THYROXINE

Thyopac-4 is a method of determining the concentration of thyroxine in blood (T-4 value) introduced by Amersham/Searle Corporation. The test is complementary to T-3 Uptake Test which indicates the free binding capacity of the thyroxine-binding proteins. Thyroxine (T-4) is carried by the blood predominently as a complex with serum proteins. In the Thyopac-4 Test, the thyroxine is extracted from serum, and added to L. Throxine-I125 bound to thyroxine-binding protein. The proportion of radioactive thyroxine which is displaced from the protein is measured, and by calibration of the system against sera of known T-4 content, the value is derived.

Two desicated serum standards are provided in the Thyopac-4 kit. One is a zero standard (0 μgm/100 ml.) and the other a high serum standard, approximately 18 μgm/100 ml. (the precise value is given on the vial label) 1.0 ml. of distilled water is added to each of the two vials containing the standards. After 10 minutes, each vial is gently inverted and swirled to obtain a homogenous solution.

A sample of 0.5 ml. of the unknown serum (specimen to be tested) is added to 1.0 ml. of ethanol of a well defined specification

in an extraction tube. The same treatment is given to the two standards separately. After a thorough mixing, the tubes are centrifuged for 5 minutes at 2000 rpm.

Using precision pipetting 0.5 ml. of the supernatant liquid from each centrifuged extraction tube is added to the appropriate Thyopac-4 vial. The volume of extracts (obtained from the two standards) permits duplicate assays, using a single sample of unknown serum.

The contents of each vial is mixed at ambient temperature for at least 30 minutes by rotation. Two minutes are then allowed for the granules to settle down. 1.0 ml. of the supernatant is removed and transferred to a counting tube. The counting is done with radioactivity counting equipment. The count rate of each sample of supernatant is determined by collecting not less than 20,000 counts for each. The calculated mean values of each standard are plotted against the known T-4 values on a linear graph paper. A straight line is obtained by connecting the two points. The T-4 value of the unknown sample is read from this calibration line using the value obtained earlier.

Thyopac-4 Test is unaffected by the presence of iodine containing compounds, or by most drugs. However, certain drugs, specially Liothyronine, D-Thyroxine, Diphenylhydantoin and Penylbutazone, give artifically increased T-4 values. Reduced T-4 levels may be obtained in cases of nephrosis, hepatitis and chronic malnutrition. Further, thyroxine levels are affected by the concentration of thyroxine binding proteins in circulation, and abnormalities in the protein levels are associated with abnormal T-4 values.

Thyopac-4 yeilds T-4 values in terms of the weight of thyroxine in μgm per 100 ml. of serum. The normal range, given as a guide, is 4.5 to 13.0 μgm/100 ml. The Thyopac Kit comes with specific information about the standards and other details applicable to each separate set.

References for Blood Tests

1. Cartwright, G.E., "Diagnostic Laboratory Hematology," New York: Grune and Stratton, 1968.

2. Miale, J.B., "Laboratory Medicine-Hematology," St. Louis: C.V. Mosby Co., 1967.

3. Amersham-Searle, "Thyopac-4 Kit for Assay of Total Thyroxine - Description, Principle and Application," Unpublished pamphlet, G.D. Searle & Co. and the Radiochemical Centre, 1972.

APPENDIX D

TEST FORMS

BASAL METABOLIC RATE

Test No.: .... Date: .... Time: ....

Name: .... Sub. No.: ....

Age: .... Ht.: .... cm. Wt.: .... kg.

Body Surf.: ...... sq. m. Room temp.: ...... °C Press.: ..... mm. Hg.

Corr. Fac.: .... O_2: .... CO_2: ....

Vol.: .... + Feed-in Sample: .... = ... lit.

1 min. Exp. Vol.: $\frac{\text{Tidal Vol.}}{\text{Sample Time}}$ = ... lit.

Tital Vol. (Exp.): $\frac{\text{1 min. Exp. Vol.}}{\text{RR = ...}}$ = ... ml.

RQ: .... Cal. Value: ....

BMR Standard: .... Kcal/sq.m/hr.

BMR .... Kcal/sq.m/hr. = ...%

Remarks: ....

....

METABOLIC RATE

Test No. ....

Name: .... Sub. No.: ...... Date: ....

Time: .... Room temp.: .... °C Press.: .... mm. Hg.

Corr. Fac.: .... O_2: .... CO_2: ....

Vol.: .... + Feed-in Sample: .... = lit.

O_2/min.: .... ml. CO_2/min.: .... ml.

RQ.: .... HR.: ....

1 min. Exp. Vol.: $\frac{\text{Total Vol.}}{\text{Sample Time}}$ = ... lit.

Tidal Vol (Exp.): $\frac{\text{1 Min. Exp. Vol.}}{\text{RR = ...}}$ = ... lit.

Remarks: ....

....

BMR CALCULATION

Q, R, S, T, U, V, W, X, Y and Z are hypothetical values.

Body surface area (cm^2) = Weight $^{0.425}$(kg.) x Height $^{0.725}$(cm.) x 71.84, as given by DuBois = Q converted into sq. m.

Volume of exhaled gases collected and corrected to STPD = R lit.

Sample collection time = S min.; R ÷ S = volume of exhaled gases in 1 minute = T lit.

Using gas analysis readings:

O_2 absorbed in 1 minute = U lit.

CO_2 eliminated in 1 minute = V lit.

V ÷ U = Respiratory Quotient

O_2 absorbed in 1 hour per 1 sq. m. of body surface = U x 60 ÷ Q = W lit.

Caloric value of 1 lit. of O_2 at an assumed Respiratory Quotient of .82 = 4.825 Kcal.*

Conversion of O_2 absorbed into calories = W x 4.825 = X Kcal/sq.m/hr.

Normal standard for the age (and sex) of the subject = Y Kcal/sq.m/hr. as given by Robertson and Reid.**

BMR expressed as percentage deviation from the normal standard = $\frac{X - Y}{Y}$ x 100 = -Z% or + Z%, as the case may be.

* The mean value of Respiratory Quotient observed in this study was .82, with a very limited range in each group. Inasmuch as the caloric value of 1 liter of O_2 varies only 3 percent between Respiratory Quotients of .76 and .88, the error in the application of an assumed Respiratory Quotient of .82 is practically negligible.

** In the absence of authoritative local standards, it was necessary to adopt suitable standards used elsewhere. The normal standards of Robertson and Reid were most appropriate inasmuch as they were based on two successive observations, a procedure followed in this study as well. Further, the mean values compared favorably.

PHYSICAL WORK CAPACITY

Name: .... Sub. No.: ..... Body Wt.: .... kg.

Bike No. .... Calibration ....

Pre-test HR .... Date and Time ....

	1	2	3	4	Resist.
HR					
Pedal Rev.					

	5	6	7	8	Resist.
HR					
Pedal Rev.					

	9	10	11	12	Resist.
HR					
Pedal Rev.					

	HR	kpm				
			PWC_{170}	=	....	kpm/min.
I	....	.....	PWC_{170}/kg.	=	....	kpm/min.
II	....	.....	PWC_{130}	=	....	kpm/min.
III	....	.....	PWC_{130}/kg.	=	....	kpm/min.

Predicted Max. O_2 = ... lit. Max. O_2/kg. = ... ml.

Remarks: ....

....

APPENDIX E

RAW SCORES

METABOLIC RATE

BMR - YOGA: PRE-TRAINING

No.	Age (yrs.)	Ht. (cm.)	Wt. (kg.)	B.Surf. (sq.m.)	BT (°C)	HR (per min.)	RR (per min.)	TV (ml.)	RQ (ratio)	BMR (Kcal/ sq.m/hr.)	BMR (%)
1	18	171.5	65.6	1.76	35.6	62	13	411	0.82	41.85	+7.3
2	17	172.0	69.4	1.81	35.8	58	12	468	0.79	41.38	+6.1
3	19	175.0	70.2	1.78	35.4	56	10	446	0.85	35.40	-9.0
4	17	170.5	63.8	1.73	36.0	58	9	508	0.84	37.52	-3.8
5	19	167.0	65.2	1.73	35.6	60	11	515	0.79	41.74	+7.3
6	20	169.0	70.5	1.80	35.5	52	12	394	0.85	35.53	-7.0
7	18	174.5	72.6	1.86	35.4	56	12	410	0.83	41.03	+5.2
8	18	184.0	84.5	2.06	35.6	60	9	511	0.85	36.35	-6.8
9	18	176.5	79.5	1.95	36.0	56	10	470	0.83	38.14	-2.2
10	22	178.5	74.8	1.92	35.5	54	14	386	0.83	38.28	+4.3
11	19	178.0	80.5	1.98	35.4	58	8	530	0.85	35.75	-8.1
12	18	164.0	59.9	1.64	35.8	48	15	405	0.83	38.30	-1.8
13	20	178.0	81.0	1.98	35.7	56	14	397	0.80	41.52	+8.7
14	18	167.5	68.8	1.78	35.8	54	10	460	0.84	35.96	-7.8
15	18	172.5	75.1	1.88	35.7	62	11	425	0.78	40.44	+3.7

BMR - YOGA: POST-TRAINING

No.	Age (yrs.)	Ht. (cm.)	Wt. (kg.)	B.Surf. (sq.m.)	BT (°C)	HR (per min.)	RR (per min.)	TV (ml.)	RQ (ratio)	BMR (Kcal/ sq.m/hr.)	BMR (%)
1	18	171.5	64.9	1.76	35.6	54	11	441	0.81	42.27	+7.8
2	17	172.0	69.2	1.82	35.8	52	10	505	0.79	43.27	+8.9
3	19	175.0	71.3	1.79	35.7	54	10	448	0.79	41.89	+7.9
4	17	170.5	64.1	1.74	35.9	50	9	515	0.83	40.76	+2.6
5	19	167.0	61.7	1.70	36.4	60	9	537	0.80	40.79	+4.8
6	20	169.0	68.1	1.78	35.9	54	11	441	0.79	41.80	+8.8
7	18	174.5	74.8	1.89	36.2	52	10	453	0.84	41.06	+3.9
8	18	184.0	80.6	2.04	35.7	48	9	516	0.79	41.44	+5.7
9	18	176.5	80.5	1.96	36.0	52	9	500	0.83	39.14	-0.1
10	22	178.5	76.2	1.94	35.6	50	12	390	0.82	38.35	+1.4
11	19	178.0	78.9	1.97	36.0	58	8	526	0.81	40.12	+3.3
13	20	178.0	81.8	2.00	35.8	54	12	460	0.80	40.67	+5.9
14	18	167.5	70.7	1.81	36.0	52	10	494	0.79	41.75	+6.4
15	18	172.5	72.4	1.85	36.1	60	11	445	0.80	42.09	+7.3

METABOLIC RATE - SAVASANA

				Pre-treatment					Post-treatment					
No.	Age (yrs.)	Ht. (cm.)	Wt. (kg.)	HR (per min.)	RR (per min.)	TV (ml.)	O_2/ min. (ml.)	RQ (ratio)	HR (per min.)	RR (per min.)	TV (ml.)	O_2/ min. (ml.)	RQ (ratio)	O_2 Drop (%)
1	17	173.0	67.4	74	12	485	279	0.86	66	9	468	253	0.86	9.3
2	17	170.5	65.0	76	14	492	262	0.87	60	10	473	232	0.90	11.5
3	19	168.0	65.7	72	11	526	254	0.84	62	9	452	220	0.83	13.4
4	18	174.5	74.3	70	12	503	272	0.86	60	10	412	247	0.88	9.2
5	20	179.0	81.8	72	12	494	279	0.83	64	9	461	245	0.88	12.2
6	18	168.5	70.2	68	11	516	267	0.85	58	8	494	251	0.85	9.7
7	18	172.5	73.1	76	13	469	274	0.86	64	12	416	255	0.88	6.9

METABOLIC RATE - TM

				Pre-treatment					Post-treatment					
No.	Age (yrs.)	Ht. (cm.)	Wt. (kg.)	HR (per min.)	RR (per min.)	TV (ml.)	O_2/ min. (ml.)	RQ (ratio)	HR (per min.)	RR (per min.)	TV (ml.)	O_2/ min. (ml.)	RQ (ratio)	O_2 Drop (%)
1	19	176.0	71.4	68	10	511	250	0.86	60	6	492	212	0.86	15.2
2	20	169.5	69.6	76	9	524	269	0.84	70	8	385	219	0.84	18.6
3	18	177.5	70.6	74	11	485	261	0.86	70	9	430	221	0.84	15.3
4	18	170.5	72.1	70	12	514	253	0.85	64	9	491	221	0.86	12.6
5	21	169.0	71.7	66	12	470	259	0.87	64	8	402	212	0.86	18.1
6	19	172.5	76.8	70	10	489	284	0.85	62	9	427	238	0.86	16.2
7	20	165.0	59.9	66	11	507	223	0.85	60	8	478	195	0.86	12.6

METABOLIC RATE - CONTROL

				Pre-treatment					Post-treatment					
No.	Age (yrs.)	Ht. (cm.)	Wt. (kg.)	HR (per min.)	RR (per min.)	TV (ml.)	O_2/ min. (ml.)	RQ (ratio)	HR (per min.)	RR (per min.)	TV (ml.)	O_2/ min. (ml.)	RQ (ratio)	O_2 Drop (%)
1	19	175.0	69.8	66	14	388	282	0.85	64	12	458	275	0.84	2.5
2	18	166.0	64.6	76	12	430	258	0.86	72	11	463	249	0.86	3.5
3	22	172.0	67.0	74	16	364	303	0.83	74	13	440	292	0.84	3.6
4	18	171.5	66.8	72	12	472	272	0.85	70	11	511	264	0.87	2.9
5	20	174.5	75.0	70	13	440	309	0.85	64	11	516	295	0.83	4.5
6	21	171.5	73.8	78	11	468	247	0.87	68	9	564	239	0.85	3.2
7	17	169.5	69.2	76	10	508	254	0.86	70	10	506	243	0.83	4.3

APPENDIX F

STATISTICAL ANALYSIS OF DATA

SUMMARY TABLES

STATISTICAL ANALYSIS OF DATA

T1 = Yoga T2 = 5BX T3 = TM T4 = Control

* = Significant at .05 level

I. ONE-WAY ANALYSIS OF VARIANCE (CORRELATED SAMPLES) FOR EFFECTS OF TREATMENT (WITHIN GROUP) AND ONE-WAY ANALYSIS OF COVARIANCE (AND SCHEFFE COMPARISON) FOR COMPARISON OF TREATMENTS (BETWEEN GROUPS)

Variable & Group	Pre-trg. Mn. & SD		Post-trg. Mn. & SD		Mult. comp.	F t	P
			BMR AND OTHER BASAL MEASUREMENTS				
BMR (%)							
T1	-0.26	7.13	+5.33	3.00	-	-2.75	.016*
T2	-0.78	6.68	-1.02	6.51	-	0.33	.745
T4	+0.67	6.68	+0.90	7.14	-	-0.33	.750
	-		-		T1 vs. T2	6.91	.003*
	-		-		T2 vs. T4	0.96	.392
	-		-		T4 vs. T1	3.15	.039*
BT (°C)							
T1	35.6	0.2	35.9	0.2	-	-0.31	.763
T2	35.7	0.1	35.8	0.2	-	-0.29	.831
T4	35.9	0.2	35.7	0.1	-	-0.30	.794
	-		-		T1 vs. T2	0.28	.537
	-		-		T2 vs. T4	0.21	.601
	-		-		T4 vs. T1	0.43	.413
HR (per min.)							
T1	56.7	2.7	53.6	3.5	-	4.20	.001*
T2	55.8	4.7	52.2	3.5	-	6.74	.000*
T4	54.7	4.7	55.6	4.1	-	-1.47	.165
	-		-		T1 vs. T2	0.42	.659
	-		-		T2 vs. T4	2.67	.083
	-		-		T4 vs. T1	0.93	.404
RR (per min.)							
T1	11.3	1.8	10.1	1.2	-	4.16	.001*
T2	11.6	2.0	10.5	1.7	-	3.94	.017*
T4	10.7	1.9	11.1	2.1	-	2.35	.061
	-		-		T1 vs. T2	2.36	.108
	-		-		T2 vs. T4	0.01	.998
	-		-		T4 vs. T1	2.77	.075

Variable & Group	Pre-trg. Mn. & SD		Post-trg. Mn. & SD		Mult. comp.	F t	P
TV (ml.) STPD							
T1	454	47.4	477	40.9	-	-3.93	.002*
T2	450	38.6	455	43.1	-	2.42	.089
T4	464	43.8	460	45.3	-	2.17	.102
	-		-		T1 vs. T2	1.32	.280
	-		-		T2 vs. T4	0.05	.950
	-		-		T4 vs. T1	0.88	.422
RQ							
T1	0.82	0.02	0.81	0.02	-	2.39	.891
T2	0.81	0.02	0.82	0.03	-	1.97	.907
T4	0.84	0.03	0.82	0.03	-	2.86	.680
	-		-		T1 vs. T2	0.03	.992
	-		-		T2 vs. T4	0.01	.998
	-		-		T4 vs. T1	0.06	.847
			BLOOD TESTS				
T-4 (μgm/ 100 ml.)							
T1	5.2	1.2	6.2	0.9	-	-3.24	.006*
T2	5.5	1.3	5.4	1.3	-	0.55	.590
T4	4.9	1.3	4.7	1.1	-	-1.21	.249
	-		-		T1 vs. T2	7.23	.002*
	-		-		T2 vs. T4	0.85	.919
	-		-		T4 vs. T1	6.02	.005*
Hemo. (gm/ 100 ml.)							
T1	15.8	1.0	16.9	1.2	-	-2.43	.030*
T2	16.3	1.0	16.5	1.1	-	-0.98	.347
T4	14.9	1.2	15.1	1.0	-	0.47	.643
	-		-		T1 vs. T2	2.36	.109
	-		-		T2 vs. T4	0.07	.930
	-		-		T4 vs. T1	3.52	.059
Hemat. (%)							
T1	45.9	3.0	47.5	1.8	-	-2.18	.049*
T2	50.4	2.9	49.4	3.0	-	-1.88	.084
T4	46.1	2.6	47.0	2.3	-	0.28	.783
	-		-		T1 vs. T2	0.43	.651
	-		-		T2 vs. T4	0.23	.791
	-		-		T4 vs. T1	1.35	.271

Variable & Group	Pre-trg. Mn. & SD		Post-trg. Mn. & SD		Mult. comp.	F t	P
RBC (mil/ c. mm.)							
T1	5.4	0.5	5.9	0.8	-	-3.26	.006*
T2	5.5	0.7	5.4	0.6	-	-1.32	.201
T4	4.9	0.5	5.2	0.7	-	-1.58	.138
	-		-		T1 vs. T2	5.18	.154
	-		-		T2 vs. T4	0.71	.497
	-		-		T4 vs. T1	8.12	.057

PWC AND MAX. O_2 CONSUMPTION

Variable & Group	Pre-trg. Mn. & SD		Post-trg. Mn. & SD		Mult. comp.	F t	P
PWC_{170}(kpm/ min.)							
T1	1244	118	1260	87	-	-3.41	.087
T2	1161	89	1333	88	-	-15.63	.000*
T4	1193	117	1182	109	-	0.45	.657
	-		-		T1 vs. T2	11.53	.000*
	-		-		T2 vs. T4	33.55	.000*
	-		-		T4 vs. T1	5.15	.061
PWC_{170}/kg. (kpm/min.)							
T1	17.2	2.0	17.4	1.8	-	2.34	.083
T2	15.6	1.8	18.0	1.7	-	5.04	.009*
T4	16.9	2.1	16.6	2.0	-	2.25	.112
	-		-		T1 vs. T2	4.27	.043*
	-		-		T2 vs. T4	5.93	.006*
	-		-		T4 vs. T1	4.01	.078
PWC_{130} (kpm/min.)							
T1	549	131	640	97	-	-6.58	.000*
T2	479	90	582	69	-	-6.90	.000*
T4	537	108	540	95	-	-0.15	.879
	-		-		T1 vs. T2	0.43	.655
	-		-		T2 vs. T4	3.60	.039*
	-		-		T4 vs. T1	5.20	.010*
PWC_{130}/kg. (kpm/min.)							
T1	7.6	1.6	8.8	1.5	-	5.66	.000*
T2	6.4	1.5	7.8	1.4	-	5.97	.000*
T4	7.5	1.5	7.6	1.5	-	1.42	.436
	-		-		T1 vs. T2	3.67	.059
	-		-		T2 vs. T4	3.98	.042*
	-		-		T4 vs. T1	4.55	.017*

Variable & Group	Pre-trg. Mn.	& SD	Post-trg. Mn.	& SD	Mult. comp.	F t	P
Max. O_2 (lit/min.) STPD							
T1	3.47	0.51	3.56	0.45	-	-3.28	.098
T2	3.26	0.43	3.71	0.44	-	-15.62	.000*
T4	3.35	0.41	3.33	0.39	-	0.30	.771
	-		-		T1 vs. T2	3.67	.036*
	-		-		T2 vs. T4	10.33	.000*
	-		-		T4 vs. T1	1.45	.247
Max. O_2/kg. (lit/min.) STPD							
T1	48.1	6.0	48.9	5.0	-	2.25	.166
T2	43.9	5.0	50.0	6.0	-	6.88	.000*
T4	47.4	5.0	46.8	4.0	-	3.66	.081
	-		-		T1 vs. T2	3.52	.046*
	-		-		T2 vs. T4	4.48	.028*
	-		-		T4 vs. T1	1.11	.337

RESPIRATORY MEASURES

Variable & Group	Pre-trg. Mn.	& SD	Post-trg. Mn.	& SD	Mult. comp.	F t	P
Vit. Capacity (lit.) STPD							
T1	4.3	0.6	4.8	0.7	-	-15.62	.000*
T2	4.5	0.5	4.9	0.4	-	-12.49	.000*
T4	4.5	0.5	4.6	0.5	-	-1.55	.145
	-		-		T1 vs. T2	5.95	.056
	-		-		T2 vs. T4	60.06	.000*
	-		-		T4 vs. T1	105.41	.000*
Chest Ex. (cm.)							
T1	5.6	1.2	7.4	1.2	-	-6.09	.000*
T2	5.5	0.8	6.5	0.8	-	-3.58	.004*
T4	5.9	1.2	6.0	1.0	-	-0.84	.414
	-		-		T1 vs. T2	1.57	.224
	-		-		T2 vs. T4	3.40	.046*
	-		-		T4 vs. T1	10.72	.000*
Br.-hold. (sec.)							
T1	53.9	20.9	66.1	18.2	-	-6.99	.000*
T2	49.9	15.9	53.6	16.5	-	-4.50	.001*
T4	56.4	19.8	58.9	19.8	-	-3.00	.088
	-		-		T1 vs. T2	10.42	.000*
	-		-		T2 vs. T4	0.53	.593
	-		-		T4 vs. T1	17.33	.000*

FLEXIBILITY

Flexi. (cm.)							
T1	4.4	4.7	11.3	5.0	-	-13.27	.000*
T2	6.5	5.6	10.7	4.3	-	-7.74	.000*
T4	4.9	5.4	5.1	5.5	-	-1.31	.212
	-		-		T1 vs. T2	6.21	.005*
	-		-		T2 vs. T4	25.12	.000*
	-		-		T4 vs. T1	60.11	.000*

Variable & Group	Post-trg. Mn. & SD		Post-detrg. Mn. & SD		Mult. comp	F t	P
DETRAINING MEASUREMENTS - YOGA GROUP							
BMR AND OTHER BASAL MEASUREMENTS							
BMR (%)	5.33	3.01	4.34	2.68	-	1.73	.106
BT (°C)	35.9	0.2	35.6	0.2	-	1.29	.220
HR (per min.)	53.6	3.5	54.3	3.4	-	-1.10	.292
RR (per min.)	10.1	1.2	9.8	0.8	-	1.00	.336
TV (ml.) STPD	477	40.9	487	32.2	-	-1.88	.083
RQ	0.81	0.02	0.83	0.02	-	-1.76	.101
BLOOD TESTS							
T-4(μgm/ 100 ml.)	6.2	0.9	5.9	0.6	-	2.07	0.059
Hemo.(gm/ 100 ml.)	16.9	1.2	16.6	1.3	-	0.62	0.548
Hemat. (%)	47.5	1.8	48.1	1.4	-	1.07	0.302
RBC (mil/ c.mm.)	5.9	0.7	6.1	0.8	-	0.19	0.854

Variable & Group	Post-trg. Mn. & SD		Post-detrg. Mn. & SD		Multi. comp.	F t	P
			PWC AND MAX. O_2 CONSUMPTION				
PWC_{170} (kpm/min.)	1260	87	1251	91	-	2.03	.063
PWC_{170}/kg.	17.4	1.8	16.9	1.9	-	2.53	.141
PWC_{130}	640	97	564	95	-	4.49	.000*
PWC_{130} /kg.	8.8	1.5	7.6	1.6	-	3.07	.036*
Max. O_2(lit/min.) STDP	3.56	0.45	3.51	0.35	-	2.12	.184
Max. O_2/kg. (ml/min.) STDP	48.9	5.0	47.5	6.0	-	1.98	.214
			RESPIRATORY MEASURES				
Vit. Capacity (lit.) STDP	4.8	0.7	4.8	0.6	-	1.38	.189
Chest. Ex. (Cm.)	7.4	1.2	7.3	1.3	-	0.56	.583
Br.-hold. (sec.)	66.1	18.2	57.4	19.8	-	5.72	.000*
			FLEXIBILITY				
Flex. (cm.)	11.3	5.0	6.0	4.4	-	9.24	.000*

Variable & Group	Pre-treat. Mn. & SD		Post-treat. Mn. & SD		Multi. comp.	F t	P
			METABOLIC COST OF SAVASANA AND TM				
O_2/min.(ml.) STDP							
T1	269.6	14.0	241.9	17.4	-	12.04	.000*
T3	257.0	17.4	216.9	12.0	-	13.06	.000*
T4	275.0	22.4	265.3	21.2	-	10.71	.002*
		-		-	T1 vs. T3	11.14	.001*
		-		-	T3 vs. T4	55.42	.000*
		-		-	T4 vs. T1	20.97	.000*

Variable & Group	Pre-treat. Mn. & SD		Post-treat. Mn. & SD		Multi. comp.	F t	P
HR (per min.)							
T1	72.5	4.1	62.0	4.4	-	12.88	.000*
T3	70.0	3.5	64.3	3.9	-	7.07	.001*
T4	73.1	3.8	68.9	3.5	-	3.38	.015*
	-		-		T1 vs. T3	1.59	.236
	-		-		T3 vs. T4	0.00	1.000
	-		-		T4 vs. T1	1.06	.371
RR (per min.)							
T1	12.1	1.5	9.6	1.4	-	7.982	.000*
T3	10.7	1.1	8.1	1.0	-	5.347	.001*
T4	12.6	1.8	11.0	1.2	-	4.26	.005*
	-		-		T1 vs. T3	0.53	.599
	-		-		T3 vs. T4	1.78	.202
	-		-		T4 vs. T1	0.34	.713
TV (ml.) STDP							
T1	498	22	454	31	-	12.21	.000*
T3	500	18	444	40	-	13.61	.000*
T4	439	46	494	39	-	-4.36	.005*
	-		-		T1 vs. T3	0.19	.825
	-		-		T3 vs. T4	7.07	.006*
	-		-		T4 vs. T1	5.53	.014*
RQ (ratio)							
T1	0.85	0.02	0.86	0.03	-	4.59	.941
T3	0.85	0.01	0.85	0.02	-	2.15	.898
T4	0.85	0.02	0.84	0.01	-	4.37	.820
	-		-		T1 vs. T3	0.37	.942
	-		-		T3 vs. T4	0.03	.867
	-		-		T4 vs. T1	0.14	.671

II. ONE-WAY ANALYSIS OF VARIANCE-REPEATED MEASURES (CORRELATED SAMPLES) AND CORRELATED t TEST

PULSE DECELERATION - YOGA GROUP
AFTER EXERCISE

Treatment	HR EX. (per min.) Mn.	HR 1 min. Sit. (per min.) Mn.	HR 3 min. Treat. (per min.) Mn.	Multi. comp.	P
A: Sitting	181	129	112	-	-
B: Mild Ex.	186	131	109	-	-
C: Savasana	184	130	101	-	-
-	-	-	-	A vs. B	.000*
-	-	-	-	B vs. C	.000*
-	-	-	-	C vs. A	.000*

III. t TESTS

PULSE DECELERATION - YOG AND CONTROL GROUPS
RELAXATION

Group	Pre-trg. Supine HR (per min.) Mn.	Post-trg. Supine HR (per min.) Mn.	Post-trg. Savasana HR (per min.) Mn.	Mult. comp.	P
T1	A:72.6-68.0 =4.6		B:74.0-60.1 =13.9	-	-
T4	-	C:75.6-67.1=8.5	-	-	-
	-		-	A vs. B	.000*
	-	-	-	B vs. C	.000*

MAXIMAL HEART RATE - YOGA GROUP

Variable & Group	Pre-trg. Mn. & SD		Post-trg. Mn. & SD		Multi. comp.	F t	P
HR							
T1	198.6	6.1	196.2	5.8	-	0.56	.582